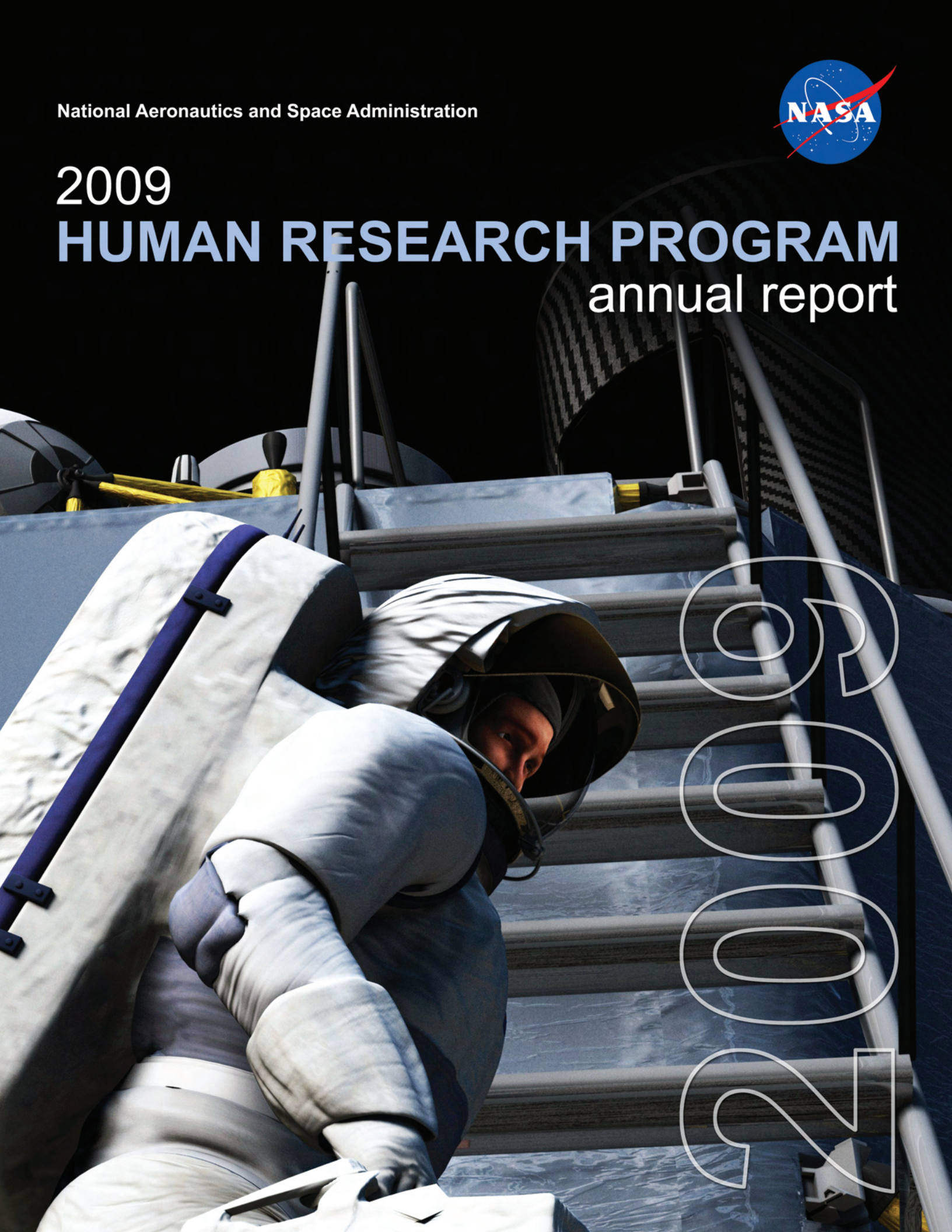
National Aeronautics and Space Administration

2009
HUMAN RESEARCH PROGRAM
annual report



Cover: Concept artwork of an astronaut exiting an exploration-class vehicle ready to begin work.

2009 will be remembered at NASA for several landmark events: Augustine Commission report, the appointment of NASA Administrator Charles Bolden, the Ares Program "back-to-back successes" with the Ares I-X test flight and ground test firings, the Hubble repair mission, the discovery of water on the Moon, the expansion of the crew on the International Space Station, the closing of the Space Shuttle external tank production line, and the Apollo 11 Fortieth Anniversary. These events portend changes in strategic direction of human spaceflight, but remind us of the solid foundation we created for NASA's Human Research Program.

2009 was the year that the Program completed its basic management foundation. We transitioned from creating building blocks to full execution of the management tools for an applied research and technology program. As a team, we continue to deliver the answers and technologies that enable human exploration of space. While the Agency awaits strategic direction for human spaceflight, the Program is well positioned and critically important to helping the Agency achieve its goals.

We delivered many key products described in this report, which supported the design of the Constellation Program's vehicles, missions, and architectures. We played an important role in determining what research will be needed on the Moon to go further in the solar system. We made several practical advances in keeping crew healthy while in the microgravity environment of the International Space Station. We used our Integrated Research Plan (IRP) to demonstrate how we are attacking the gaps in our knowledge and recommending technological solutions. The publicly available IRP allows the Program to describe to scientists, who may be new to our problems, the relationship between the tasks we are working and exploration needs. The plan helped us more closely align our work with exploration mission risks and involve scientists nationally and worldwide in developing solutions and products for human space exploration.

We made strides in publishing our Evidence Book, which provides a comprehensive review of the evidence used to evaluate a risk. The Evidence Book addresses the long-standing issue of keeping what we learned in the past 40 years clearly organized and available. We plan to keep this reference material up-to-date and subject to continuous scientific review.

We continued to engage the U.S. research and commercial communities through 3 research solicitations, a Small Business Innovative Research solicitation, 2 innovation challenges, and a variety of workshops and working groups. The largest annual solicitation for multidiscipline space biomedical research was again issued jointly between NASA and the National Space Biomedical Research Institute.

The Program is making extensive use of the International Space Station to address the issues of maintaining human health and performance during and after long-duration spaceflight. We conducted an average of 10 experiments per increment to further our solutions to mitigate bone loss and decreased cardiovascular capacity as well as track changes in spacecraft microbes and the human immunological function. Human research is one of the most active U.S. research areas on the International Space Station.

This year we continued to strengthen our partnerships with domestic agencies and the international space life sciences community. The National Space Biomedical Research Institute completed 3 experiments using the Russian 105-day isolation and confinement study. We delivered the Muscle Atrophy Research and Exercise System to the International Space Station. This system is a joint effort between the European Space Agency and NASA, and is located and operated in the Columbus module of the International Space Station.

We expanded our education and outreach activities, creating one of the most exciting international educational and outreach programs involving 8 nations. The Space Explorer International: Fitness Challenge involves nutrition, exercise, and healthy lifestyle choices using a space theme and the International Space Station crews.

We continue to become better organized, more productive, and focused on the right things to ensure a highly successful, human space exploration program.

Dennis J. Grounds
Program Manager

Table of Contents

Human Research Program Overview

Background

Crew health and performance is critical to successful human exploration beyond low Earth orbit. Risks include physiologic effects from radiation, hypogravity, and planetary environments, as well as unique challenges in medical treatment, human factors, and behavioral health support. The Human Research Program (HRP) investigates and mitigates the highest risks to human health and performance, and provides essential countermeasures and technologies for human space exploration.

In the fourth year of operation, the Program continued implementation of the evidence-risks-gaps-tasks-deliverables management architecture. Products were delivered to support the preliminary design of the Constellation Program vehicles. Experiment operations continued on the International Space Station (ISS) and in ground analogs, providing data to further understand the impact of the space environment on the human system. These research results contributed to the scientific knowledge and technology developments to address the human health and performance risks.

As indicated in this report, the Program made significant programmatic and scientific progress towards reducing crew health and performance risks and advancing medical care and countermeasure systems for missions to the Moon and other exploration destinations.

Goal and Objectives

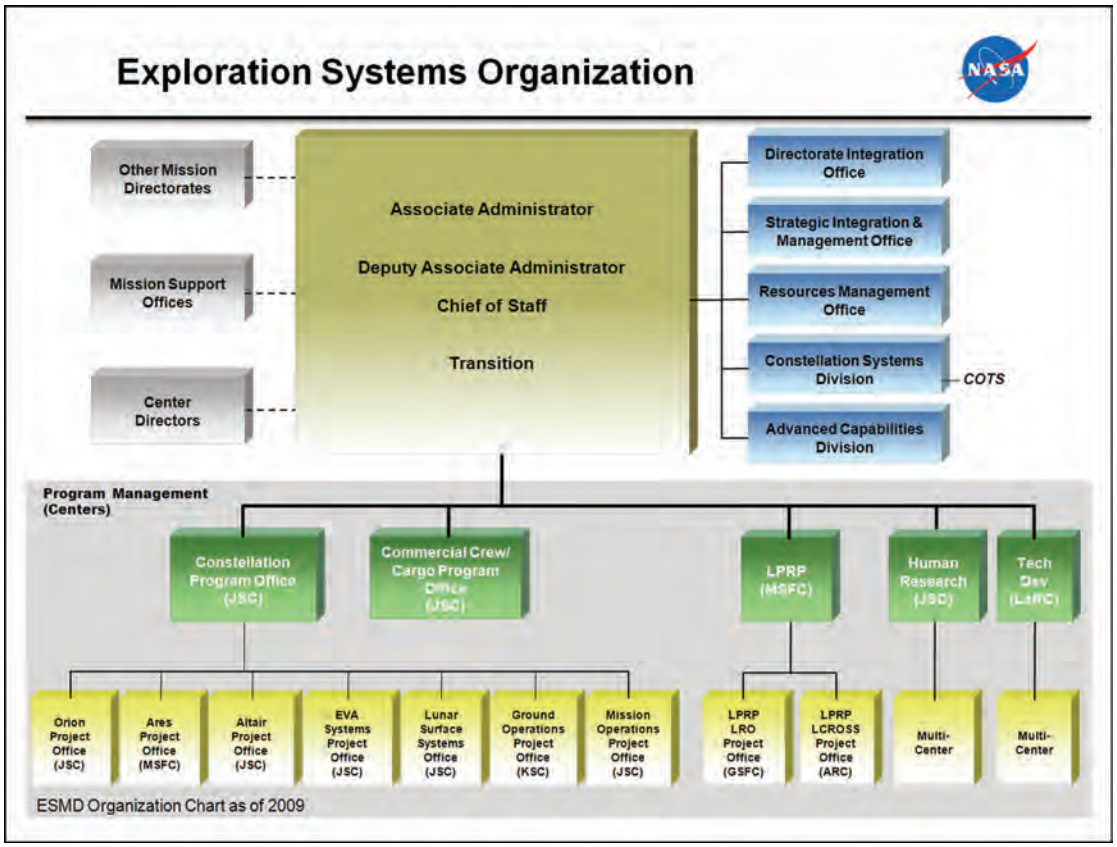
The goal of the HRP is to provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration. The specific objectives of the HRP are:

1. Develop capabilities, necessary countermeasures, and technologies in support of human space exploration, focusing on mitigating the highest risks to crew health and performance. Enable the definition and improvement of human spaceflight medical, environmental and human factors standards.

2. Develop technologies that serve to reduce medical and environmental risks, to reduce human systems resource requirements (mass, volume, power, data, etc.) and to ensure effective human-system integration across exploration mission systems.
3. Ensure maintenance of Agency core competencies necessary to enable risk reduction in the following areas: space medicine, physiological and behavioral effects of long duration spaceflight on the human body, space environmental effects, including radiation, on human health and performance and space human factors.

Program Organization

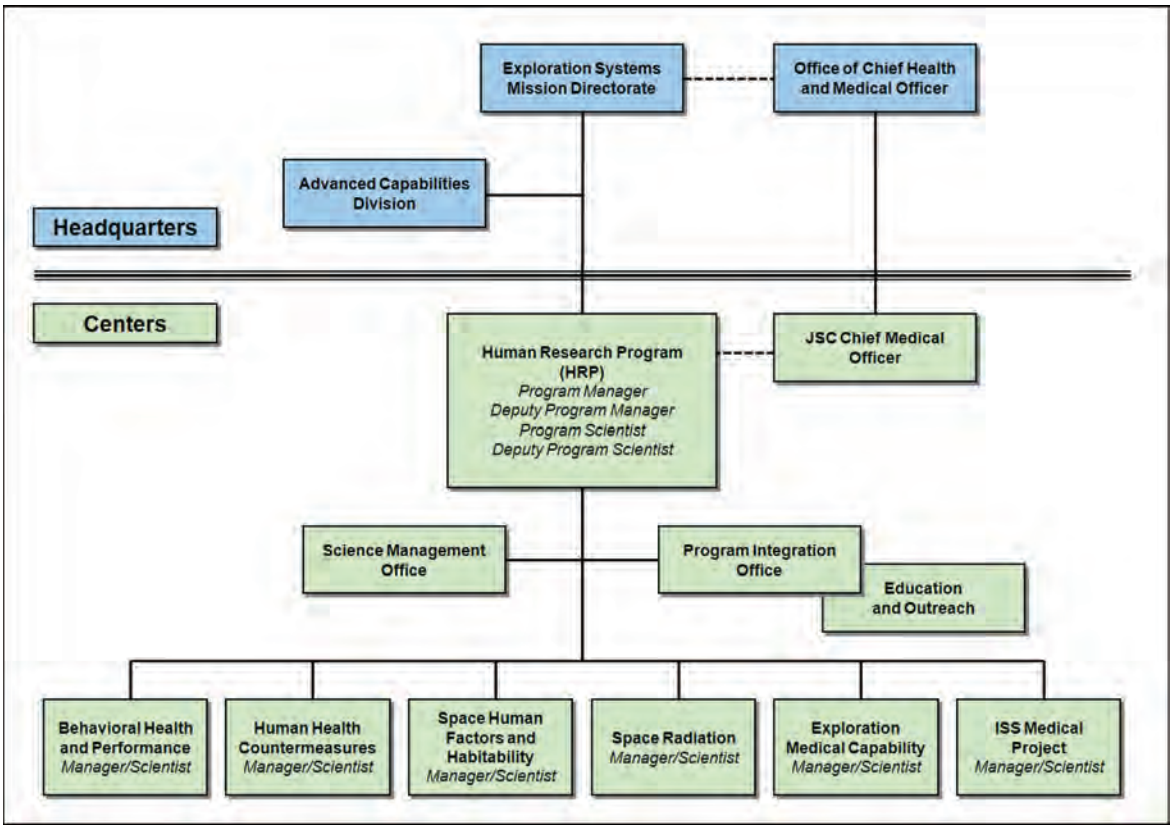
Strategically, the Program conducts research and technology development that: (1) enable the development or modification of Agency-level human health and performance standards by the Office of the Chief Health and Medical Officer and (2) provide the Exploration Systems Mission Directorate with methods of meeting those standards in the design, development, and operation of mission systems. The Program resides within the Exploration Systems Mission Directorate.



2009 Organizational Structure of the Exploration Systems Mission Directorate including the HRP

The Program's organization is designed to support and accomplish the goals of the Exploration Systems Mission Directorate and Office of the Chief Health and Medical Officer. The Program Manager and Deputy Manager lead all aspects of the Program. The Program Scientist and Deputy Scientist lead the science management and coordination. Two offices support program and science management and provide integration across the Program.

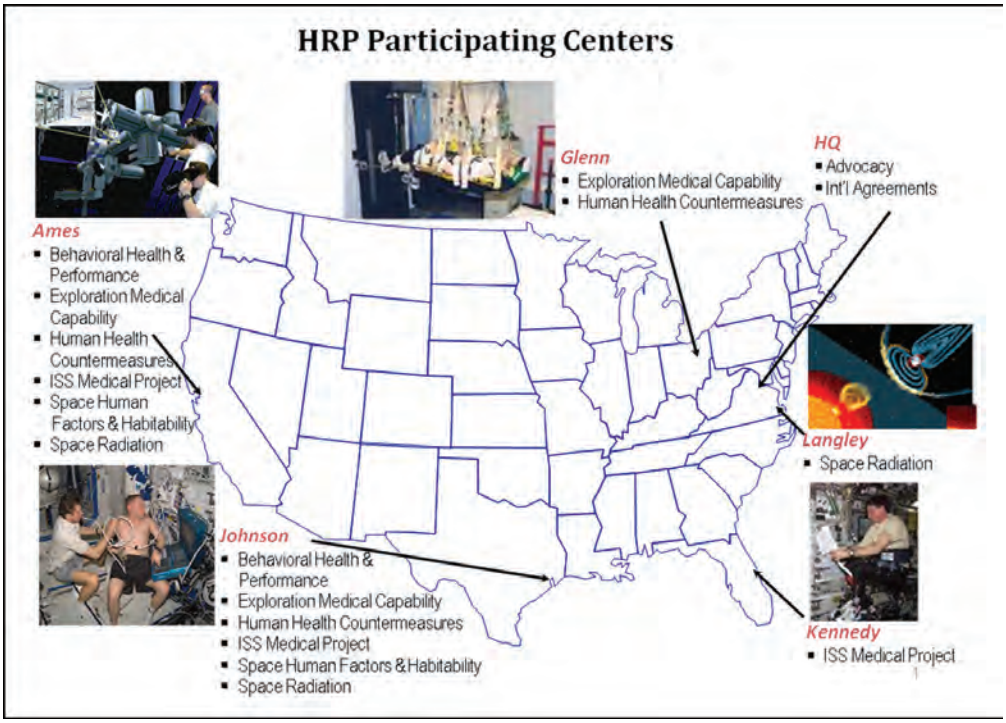
There are 6 elements that comprise the Program and are focused to accomplish specific goals for investigating and mitigating the highest risks to astronaut health and performance.



HRP Organizational Structure

The Science Management Office and Program Integration Office provide key integration of activities across the Program in support of the Program Manager, Program Scientist, and all other components of the Program. The Science Management Office maintains scientific integrity of the Program's research and reviews and integrates science tasks across the Program, reviews the prioritization and implementation of flight and ground analog tasks, communicates research needs to other programs within NASA (e.g., Constellation), and cultivates strategic research partnerships with other domestic and international agencies. The Program Integration Office provides program planning, integration, and coordination across the Program. This office ensures close coordination of customer needs and the Program's deliverables to meet those needs.

The Program is divided into 6 major elements: ISS Medical Project, Space Radiation, Human Health Countermeasures, Exploration Medical Capability, Space Human Factors and Habitability, and Behavioral Health & Performance. These elements provide the Program's knowledge and capabilities to conduct research to address the human health and performance risks as well as advance the readiness levels of technology and countermeasures to the point of transfer to the customer programs and organizations. Each component consists of the aggregation of related projects and research tasks focused toward developing products that reduce risks to the crew. Management of the Program is located at the Johnson Space Center (JSC).



Additional information about the Human Research Program can be found at: **http://www.nasa.gov/exploration/humanresearch**.

Partnerships and Collaborations

The Program works with universities, hospitals, federal, and international agencies for the purpose of sharing research facilities, multi-user hardware, and for collaboration on research tasks of mutual interest. The Program uses bed rest facilities at the University of Texas Medical Branch in Galveston, TX, as a spaceflight analog to study changes in physiologic function associated with spaceflight. The NASA Space Radiation Laboratory at the Department of Energy's (DoE) Brookhaven National Laboratory is used to conduct research using accelerator-based simulation of space radiation. The Program also uses radiation research facilities at the Loma Linda University Medical Center.

The National Space Biomedical Research Institute (NSBRI), an academic institute funded by the Program, investigates the physical and psychological challenges of long-duration human spaceflight. Founded in 1997 through a NASA competition, the NSBRI is a nonprofit research consortium that bridges the research, technical, and clinical expertise of the biomedical community with the scientific, engineering, and operational expertise of NASA. Additional information on the NSBRI can be found at **http://www.nsbri.org/index.html**.

The General Clinical Research Center and the Lerner Research Institute at the Cleveland Clinic/University of Washington provide facilities supporting the Program. These facilities provide bed rest and 6-degree head-down tilt simulation along with a zero-gravity locomotion simulator, a horizontal treadmill providing footfall forces and conditioning similar to that of the treadmill used on the ISS.

The Program also maintains collaborative relationship with the International Partners through various working groups. These relationships enhance the research capabilities and provide synergism between the research efforts among countries.

Examples of Partnerships and Collaborative Relationships with Universities, Industries, and Government Agencies

National Space Biomedical Research Institute	Bridges the research, technical, and clinical expertise of the biomedical community with the scientific, engineering, and operational expertise of NASA
International Space Life Sciences Working Group with members from Canada, Japan, Germany, Ukraine, France, and the European Space Agency (ESA)	Optimizes collaborative research with ground analogs
Joint Working Group with Russia	Synergy in research and operations, optimal use of the ISS
National Institutes of Health (NIH), the Department of Energy, the Centers for Disease Control and Prevention, the Department of Agriculture, and the Department of Defense	State-of-the-art research facilities, research activities, and technology development of mutual interest
Cleveland Clinic/University of Washington	General Clinical Research Center – BioEngineering and School of Medicine provide facilities in support of HRP research
Aquarius Habitat (NASA Extreme Environment Mission Operations [NEEMO] operated by the University of North Carolina) and other analog environments such as Antarctica and Devon Island	Perform research in analog environments in the areas of physiologic adaptation, medical technology, and behavioral health and performance
University of Texas Medical Branch	Bed rest facilities
Brookhaven National Laboratory	State-of-the-art facility to perform radiobiology and physics experiments
Loma Linda University	Space radiation research and facilities
European Union in Radiobiology Research Program	Space Radiation research
International Council of Radiation Protection	Recommendations for radiation protection in space
Massachusetts Institute of Technology (MIT) Man-Vehicle Laboratory	Working to define the role of the human in complex space systems

The Program organizes international coordination meetings and participates in and coordinates research and technology workshops to inform researchers outside of NASA about the Program's research and for the Program's researchers to obtain information not available within NASA.

International Coordination Meetings and Research and Technology Workshops

Meeting	Meeting Description
International Space Medicine Summit III http://webcast.rice.edu/webcast.php?action=details&event=1923	Discussions on research needed to prevent and mitigate medical and biomedical challenges associated with long-duration spaceflight
36th International Space Life Sciences Working Group (ISLSWG) and the 6th International Workshop on Space Microbiology with member agencies http://www.nasa.gov/exploration/about/islswg.html	Works to bring agencies together to provide more complete coordination of international development and use of spaceflight and special ground research facilities, by identifying the agencies' mutual interests and programmatic compatibilities, enhancing communication, and encouraging a unified effort among and between the participating space life sciences communities around the world
12th Meeting of the US-Russian Joint Working Group on Space Biomedical and Biological Sciences Research	Discuss space biology and space medicine emphasizing ISS research and opportunities for collaboration, and education and outreach opportunities to inspire the next generation of scientists and physicians who will work in future human spaceflight endeavors
6th International Workshop on Space Microbiology	Discuss space-related microbiological research activities
Humans in Space http://iaa-his2009.imbp.ru/index00e-e.html	Share information among international agencies and researchers including obtaining information on progress in countermeasure research and development by international researchers
Human Research Program Investigators' Workshop http://www.dsls.usra.edu/meetings/hrp2009/	Tutorials and panel discussions to address opportunities, processes, resources, and strategies to optimize HRP research
Papilledema Summit	To understand anatomic and physiologic changes that may predispose crewmembers to changed visual acuity, to review and understand NASA's current capabilities, and to formulate recommendations for prevention
60th International Astronautical Congress Space Life Science Symposium http://www.iafastro.com/?title=IAC2009	Share information about space for sustainable peace and progress and information on HRP Education and Outreach activities
20th Annual NASA Space Radiation Investigators' Workshop in conjunction with the Heavy Ions in Therapy and Space Symposium	Focused on the effects of heavy ions on biological systems that are of critical importance for interplanetary human exploration
3rd Annual Systems Radiation Biology Workshop http://www.sysradbio2009.org/	Space radiation collaboration with European Union's Non-targeted Effects of ionizing radiation scientists on non-targeted research and models of radiation-induced arthrosclerosis and its causal relation to coronary heart disease and stroke found in populations exposed to low and moderate doses of radiation

Meeting	Meeting Description
Intervertebral Disc (IVD) Damage Workshop	To determine the risk of IVD damage following spaceflight, evaluate the need for crewmember testing, and identify potential countermeasures to mitigate the perceived risk of IVD damage; combined outcomes of workshop and preliminary manuscript used to develop NRA requested research
NSBRI-sponsored In-flight Laboratory Analysis Workshop	To provide a forum for key members of the research community to learn more about technological approaches available for analyzing biological fluids, and the requirements for developing biomedical fluid analyzers for space biomedical research
Alterations in Host-Microbe Interactions Workshop	Panel of internal and external experts discuss alterations in host-microbe interactions and the impact of how the interplay between the human immune system and the invading microorganism determines if infection and disease will occur
Behavior Health and Performance Autonomy Workshop	To identify HRP's research needs for self-regulation of a team in semi-autonomous environments within the context of exploration missions

Major Programmatic Accomplishments

Standing Review Panels

The purpose of the Program's external Standing Review Panels (SRPs) was to review the strategy of the Program and the overall strengths and weaknesses of the Integrated Research Plan (IRP), and to provide recommendations for improvement. Panel members included university faculty; NASA civil servants; non-NASA civil servants from the military, DoE, and Centers for Disease Control and Prevention; and representatives from industry. The content of final reports received to-date have offered new or unique suggestions for improvement and commended NASA for soliciting outside review of its Human Research Program.

Input from these SRPs will be used to benefit Program implementation and further align tasks with the most important gaps in knowledge to enable the Program to make even more significant programmatic and scientific progress towards reducing crew health and performance risks and advancing medical care and countermeasure systems for missions to the solar system and beyond. The panels will convene no less than biennially to provide updated recommendations to the Program.

NASA-STD-3001, Space Flight Human-System Standard Volume 2 (SFHSS V2) and the Human Integration Design Handbook (HIDH)

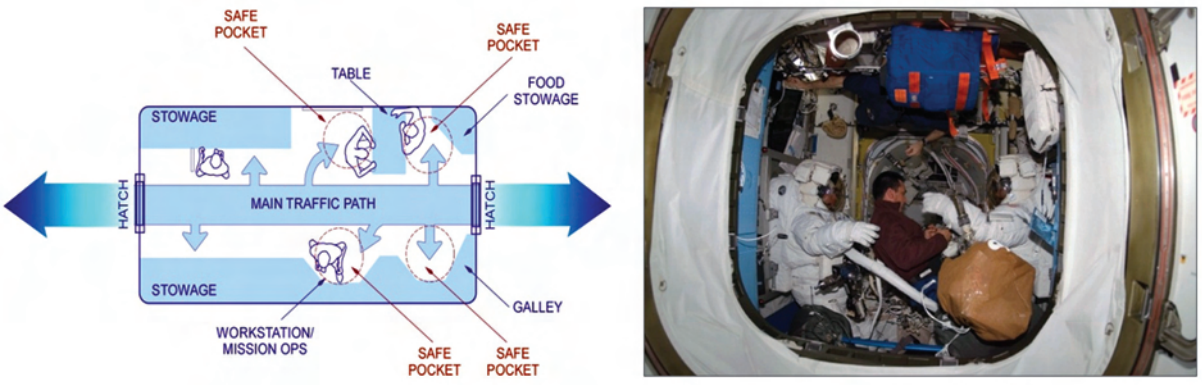
NASA created the Man-System Integration Standards (NASA STD-3000) in 1985 to establish human engineering standards for human spaceflight and to make the ISS more habitable and "user-friendly". Since then many important lessons have been learned from flying the Space Shuttle and living in the ISS, and researchers within NASA and across the country have developed better ways to design displays and controls, to provide an environment for living and working, and to keep crews healthy in space. New technologies and information from 24 years of progress has led to the need to revise and update NASA-STD-3000.

In response to this need, NASA-STD-3001, Space Flight Human-System Standard Volume 2 (NASA-STD-3001, V2) and the Human Integration Design Handbook (HIDH) were developed

to supersede NASA-STD-3000. Volume 2 contains standards for human spaceflight from the human and environmental factors disciplines. The HIDH is a companion document containing human-system integration data and lessons learned from previous human programs – a compendium of human spaceflight history and knowledge. It is organized in the same sequence as NASA-STD-3001, V2, and provides useful background information and research findings to support the development of program level requirements. The HIDH is intended to aid interpretation of V2 standards and to provide guidance for requirement writers and vehicle and habitat designers.

Development of these documents required significant contribution and collaboration across NASA. NASA-STD-3001, V2 was sent to the NASA Engineering Standards Program for Agency review and the HIDH was published though the JSC's Scientific and Technical Information Program and made available as a special publication, NASA/SP-2010-3407 (**http://ston.jsc.nasa.gov/collections/TRS/_techrep/SP-2010-3407.pdf**).

The Agency-wide review of V2 was completed in October 2009 and disposition of review comments was completed. The standard is on schedule for final baselining through the NASA Technical Standards Program in early 2010.



NASA-STD-3001, V2 specifies clearances for traffic paths (left). Large amounts of stowage on ISS (right) make it difficult to maintain these pathways.

Human System Risk Board – HRP Risk Mitigation Analysis Tool (RMAT)

The purpose of the RMAT is to establish a baseline of the risk management approach for each human health and performance risks. The RMAT captures information such as risk context, mission applicability, likelihood and consequence, and contributing factors of the risk. The RMATs for 26 of the 27 Program risks identified in the HRP Program Requirements Document (PRD) were presented to the Human System Risk Board in 2009. Of the 26 RMATs presented thus far, a baseline for 14 risks has been approved by the Board; the remaining 12 are either being evaluated by the Board or are currently undergoing revisions.

Solicitations

NASA, in partnership with the NSBRI, finalized decisions on proposals submitted in response

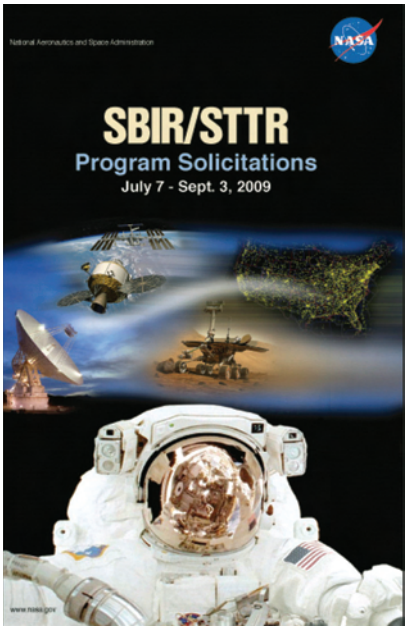
to the 2008 NASA Research Announcement (NRA), “Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions (NNJ08ZSA002N)” in March 2009. Twelve proposals were selected and announced in April 2009. Five of the projects joined the Program’s team of principal investigators, while 7 joined the NSBRI’s team-based research program.

The NRA for Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions was released in July 2009. This NRA jointly solicited proposals for NASA and the NSBRI in support of the Program. Proposals were solicited by NASA in the areas of Sensorimotor, Muscle and Bone, Cardiovascular and Muscular Endurance, Intervertebral Disc Damage, and Advanced Food Technology. NSBRI solicited proposals in the areas of Cardiovascular Alterations and Smart Medical Systems and Technology. Peer-review of the NASA and NSBRI Step-2 proposals will occur in early 2010. Final NRA selections will be announced in April 2010.

NRA NASA Specialized Centers of Research (NSCOR) “Carcinogenesis and Central Nervous System Risks from Space Radiation (NNJ08ZSA003N)” was released in September 2008 and 4 awards were announced in April 2009. This key research will help the Space Radiation Element reduce the uncertainty in cancer risk estimation for astronauts and quantify the magnitude of deleterious effects to the central nervous system as a result of space radiation exposure.

The NRA “Ground-Based Studies in Space Radiobiology (NNJ09ZSA001N)” Radiation NSCOR was released in March 2009. This NRA solicited ground-based proposals for the Program’s Space Radiation Element. Specific areas of emphases included: (1) Radiation Quality Dependence of Carcinogenic Risk, and (2) Late Central Nervous System and Degenerative Risks from Space Radiation. Proposals were solicited in the area of Space Radiation Biology using beams of high energy heavy ions simulating space radiation at the NASA Space Radiation Laboratory at Brookhaven National Laboratory. A peer review was conducted in August to evaluate the proposals and 12 awards were announced in October 2009.

The NASA Small Business Innovation Research (SBIR) Program Management Office released the SBIR Phase 1 Solicitation in July 2009. The 5 Program topics included in the solicitation were Exploration Crew Health Capabilities, Behavioral Health and Performance, Space Human Factors and Food Systems, Space Radiation, and In-flight Biological Sample Preservation and Analysis. Eleven HRP awards were announced in November 2009. In addition, 12 HRP 2008 SBIR Phase 2 awards were announced in October.



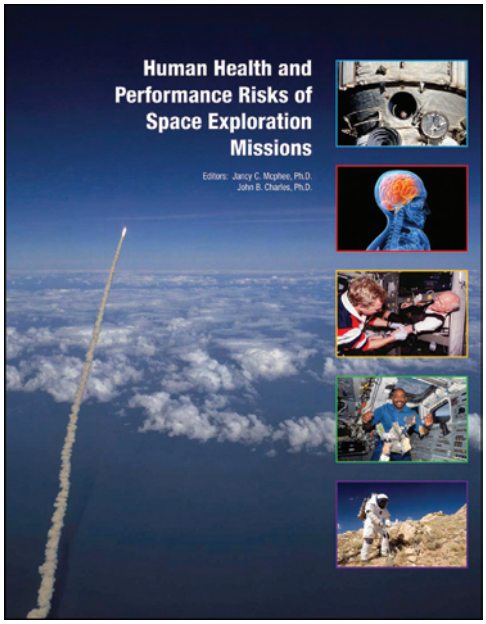
2009 SBIR Solicitation Cover

Open Innovation

The Program is participating in an open innovation experiment with the Space Life Sciences Directorate (SLSD) at JSC. The goal of the experiment is to use current SLSD/HRP technology and knowledge gaps as a pathfinder in moving toward a more distributed innovation model. Two open innovation service providers (OISPs) were chosen to seek out potential solution providers. The purpose of this effort is to test the viability of an external OISP provider with NASA's specific knowledge and/or technology gaps. Two of the challenges (NASA Challenge: Mechanism for a Compact Aerobic and Resistive Exercise Device and NASA Challenge: Improved Barrier Layers ... Keeping Food Fresh in Space) were posted December 23, 2009 with rewards of $20,000 and $15,000, respectively. For information on these challenges, go to **http://www.innocentive.com/about-us-open-innovation.php**.

Evidence Book

The Program's Evidence Book is a collection of evidence-based risk reports for each risk contained within the HRP PRD. The book "Human Health and Performance Risks for Space Exploration Missions", is available in paperback or electronically. It provides a current record of the state of knowledge from ground and space research and operations for each of the defined human health and performance risks for future NASA missions and may be accessed at **http://humanresearch.jsc.nasa.gov/elements/smo/hrp_evidence_book.asp**.



HRP Performance Risks of Space Exploration Missions book

Major Technical Accomplishments

Renal Stone Countermeasure Office of Chief Health and Medical Officer Operational Readiness Review (Human Health Countermeasures Element)

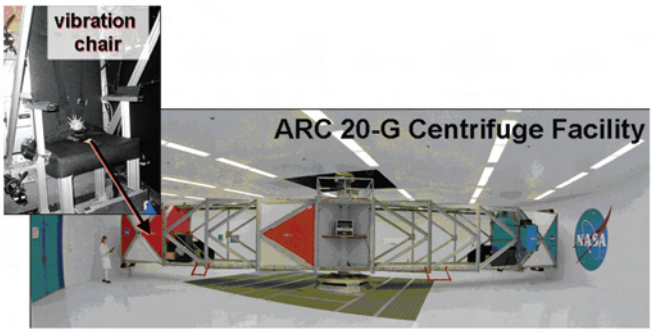
Following completion of the Renal Stone Countermeasure investigation, flight operations, and data analysis in 2008, the JSC Chief Medical Officer approved proceeding to transition the potassium citrate recommendation to medical operations. In June 2009 the NASA Headquarters Office of the Chief Health and Medical Officer conducted an operational readiness review of the potassium citrate countermeasure for the prevention of renal stones in spaceflight. The expert review panel unanimously recommended that the countermeasure be approved for operational use. On June 30, 2009 the NASA Headquarters Office of the Chief Health and Medical Officer issued a memo formally approving operational use of this countermeasure.

The results of this research investigation directly addressed a major health concern of the Program. The findings of the investigation were documented in the *Journal of Urology* in November 2009.

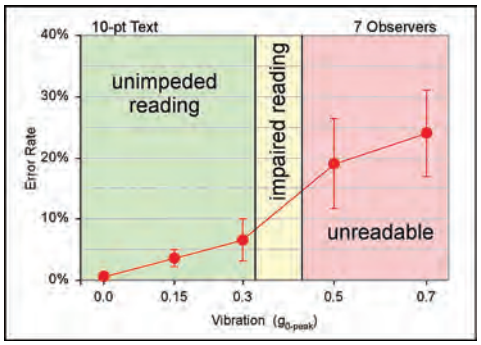
Vibration Chair – Effects of Thrust Oscillation Vibration on Maintaining Situation Awareness and Assuming Manual Flight Control (Space Human Factors and Habitability Element)

Constellation Program analyses indicate that the Orion crew vehicle could experience heightened vibration caused by thrust oscillation in the Ares-I launch vehicle just before first-stage separation. In 2009, a joint HRP and Constellation Program'study examined the effects of thrust oscillation vibration on the ability of 13 astronaut office participants to maintain situational awareness of an evolving flight simulation and to then hand-fly the spacecraft shortly after the vibration was stopped. During each trial, participants seated in a semi-supine chair were repeatedly exposed to vibration in the body x-axis (chest-to-spine direction).

Participants made a speeded judgment as to whether the behavior of the pitch rate indicator, pitch needle, and predictor dots along the ascent trajectory line elements on a prototype Orion primary flight display (PFD) provided consistent information, or, if not, which one of these 3 elements was inconsistent with the others. Two seconds after the vibration ended, participants provided joystick inputs to null PFD indicators of pitch and roll errors. The results from this study guided the Constellation Program's establishment of vibration limits (i.e., launch and crew vehicle design requirements) to ensure sufficient display usability by the crew during periods of ascent thrust oscillation.



Vibration Chair on Ames Research Center's 20-G Centrifuge



Astronaut Office participants' objective reading performance (error rate) superimposed on subjective assessment of display readability (green-yellow-red background) for 10-point numeric text

Significant Facility Hardware and In-flight Accomplishments (International Space Station Medical Project)

Portable Pulmonary Function System

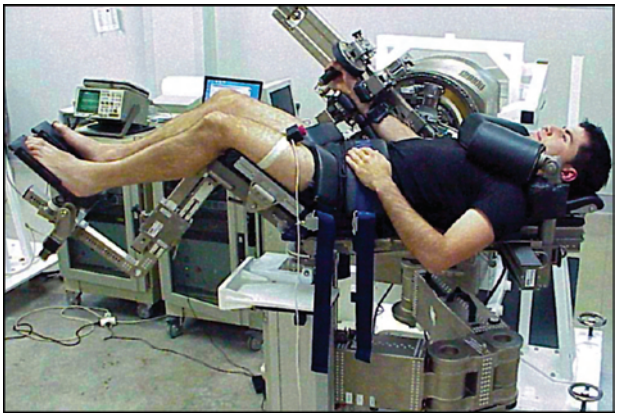
Through a cooperative agreement, the portable pulmonary function system (PPFS) is a joint NASA and ESA pulmonary physiology instrument. ESA provided the PPFS to NASA for use as a metabolic gas analysis system used to measure both peak exertion and cardiac output. The PPFS was designed for use in all parts of the ISS enabling metabolic measurements during exercise.

Crewmember Works with the PPFS Hardware Freely Floating in the Destiny Laboratory

Following the successful flight instrument checkout during the summer of 2009 on the ISS, the instrument was used to document changes in maximum oxygen uptake for crewmembers during long-duration missions. The PPFS is also capable of measuring expiratory reserve volume, respiratory exchange ratio, total lung capacity, volume of pulmonary capillary blood, cardiac output, and fractional inspiratory and expiratory volumes.

Muscle Atrophy Research and Exercise System (MARES)

The Muscle Atrophy Research and Exercise System (MARES) is a joint ESA and NASA physiologic research facility that will be used on the ISS to carry out research on musculoskeletal, biomechanical, and neuromuscular human physiology. Results from this research will provide a better understanding of the effects of microgravity on the muscular system and evaluation of the countermeasures designed to mitigate muscle atrophy.



Ground-based Testing of the MARES Hardware

The MARES instrument was provided by ESA and NASA is responsible for integrating the device into a rack for launch and on-orbit operations. In 2009, all flight certifications were received and the instrument was delivered to the KSC in preparation for delivery to the ISS during the STS-131 mission in early 2010.

Education and Outreach

The Human Research Program Education and Outreach (HRPEO) Project is committed to using NASA's space research and exploration to educate the nation in science, technology, engineering, and mathematics. Project activities and materials target educational communities, the general public, policymakers, and the media using formal and informal venues. The HRPEO Project has made notable strides in their K-12 programs and outreach efforts. Their primary grade programs include the *21st Century Explorer*, *Fit Explorer*, and *Sports and Exploration*, while their secondary programs include *Math and Science @ Work* and *Exploring Space through Math*. The *Space Explorer International (SEI): Fitness Challenge 2010* project is in development. To learn more about HRPEO please visit **http://www.nasa.gov/exploration/humanresearch/education/index.html**.

2009 Highlights

Space Explorer International: Fitness Challenge

The Space Explorer International (SEI): Fitness Challenge is an international pilot public outreach program designed to encourage proper nutrition and exercise by teaching young people to live and eat like space explorers. Using the ISS as a venue for international collaboration, the project aims to promote healthy and active lifestyles by demonstrating to children how astronauts and cosmonauts stay physically fit during spaceflight.

The SEI is designed as an ISS focused, joint educational outreach program that will integrate fitness, nutrition, and educational content from a diverse space exploration group consisting of multiple space agencies and institutes. This group is working together to design an international challenge that can be implemented locally by each member country. The SEI is being organized and developed by the U.S. (NASA), France (CNES), Germany (DLR), and Japan (JAXA) with participation from Italy, Netherlands, Portugal, and Russia. Organization of the challenge began in 2009, with a kickoff planned in 2010, and the culminating event is scheduled for April 2011. It is hoped that this initial pilot effort will lead to other integrated educational outreach efforts on a wide range of topics supporting the science, technology, and engineering aspects of human exploration.

Texas Space Grant Consortium Space Day

HRPEO team members supported Space Day at the Texas State Capitol March 5–6, 2009 in Austin, TX. Over 3,000 educators, including home-school teachers, and students attended the 2-day event. HRPEO conducted a hands-on activity from the 21st Century Explorer project. During the activity students were encouraged to mimic robotic exploration to discover “what’s hidden inside”. The students also discovered the limitations of robotic explorers and gained an understanding of the complexities surrounding human spaceflight. Educators were provided with detailed information on the 21st Century Explorer project as well as all HRPEO education projects.

Team Member Instructs Students during Space Day on the Activity Entitled "Hidden Inside"

NASA Space Girl Fitness Symposium

Girl Scouts Participating in Activities Entitled "Crew Assembly"

HRPEO team members held the NASA Space Girl Fitness Symposium in September 2009 at a Girl Scout camp in Conroe, TX. The NASA Space Girl Fitness Symposium featured 6 of the Fit Explorer Train Like an Astronaut (TLA) physical activities (Crew Assembly, Agility Astro-course, Building an Astronaut Core, Explore and Discover, Speed of Light, and Do a Spacewalk) and 2 educational activities (Energy of an Astronaut and Hydration Station). Approximately 200 Girl Scouts participated in the symposium.

University of Texas – Pan American Hispanic Engineering Science and Technology (HESTEC) Week

HRPEO supported the University of Texas – Pan American Hispanic Engineering Science and Technology (HESTEC) Week. The program consisted of an Educator Day, Latina Day, Student Activity Days, and Community Day.

During Educator Day, team members provided a workshop highlighting the HRPEO Math and Science @ Work and Exploring Space through Algebra projects. Over 60 teachers attended this workshop, which also provided information about the projects for use in the classroom.

A Team Member Demonstrating the “Living Bones, Strong Bones” Activity

During Latina's Day, which targeted Latina girls and their mothers, HRPEO team members talked about their youth, career paths, and education. Approximately 100 girls and their mothers attended the sessions. A summary of NASA student programs was given to each of the participants. During the Student Activity Days, team members implemented the 21st Century Explorer activity, "Speed It Up" with more than 1,000 students (ranging from elementary to high school) in attendance. The activity provided students with knowledge pertaining to NASA rockets, chemical propulsion, and chemical reactions. An additional 3 activities from the 21st Century Explorer and Fit Explorer projects were presented during Community Day, which attracted several thousand people from the South Texas region. Team members also reached out to the South Texas region by presenting information on 21st Century Explorer and Fit Explorer to over 20 superintendents in the South Texas region.

5th Annual Space Life Sciences Summer Institute (SLSSI)

Sixty-four summer undergraduate and graduate students from JSC, and remotely from the Glenn Research Center, attended the Fifth Annual Space Life Sciences Summer Institute. Conducted through JSC's SLSD, the summer institute provides the opportunity for students to learn directly from the scientists, physicians, and engineers working to solve human health and performance issues related to long-duration spaceflight. The summer institute offers a unique learning environment that focuses on current biomedical issues associated with human spaceflight in support of space exploration. The objective is to expose the students to the many human health issues under investigation.

As part of the program, scientists, engineers, physicians, and astronauts delivered lectures on topics ranging from nutrition and cardiovascular physiology to environmental health concerns and cooking in space. In addition to attending the lecture series, the students participated in behind-the-scenes tours of the Neutral Buoyancy Laboratory, Mission Control, and vehicle training mockups.

SLSSI Students Touring the Mission Control Center

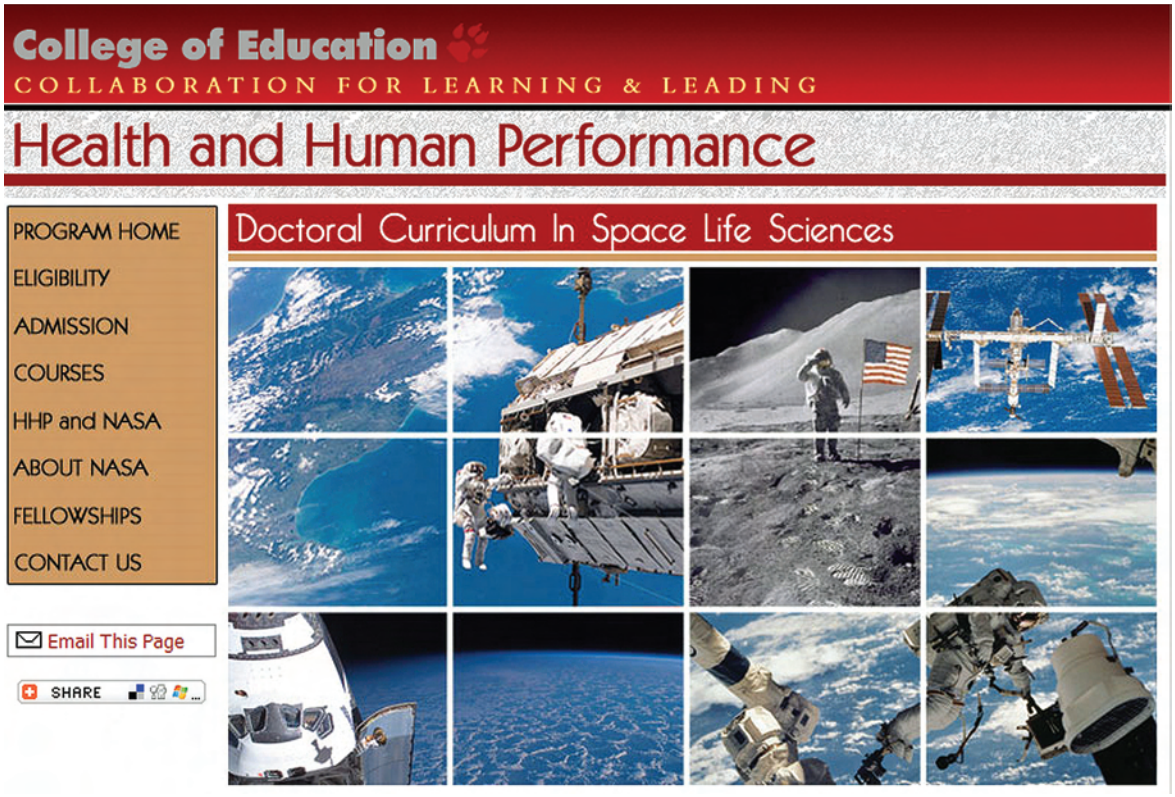
NASA Space Radiation Summer School

The Program's Space Radiation Element, in support of developing the next generation of radiobiology researchers interested in space, selected 15 students and 3 auditors to attend the 6th Annual NASA Space Radiation Summer School held at Brookhaven National Laboratory. Participants included domestic and foreign graduate students as well as faculty in biology and physics. Extensive course content included lectures and labs in radiobiology, nuclear physics and transport, health physics, radiation induced acute and late health effects, risk modeling, and radiation protection. Current and future researchers in space radiobiology can access a space radiation encyclopedia fashioned after the WIKI model at **https://three.usra.edu/index.php/THREE** to further understand this field of research.

Space Life Sciences PhD Track

The Program collaborates with the University of Houston's College of Education to offer a doctoral track in the space life sciences. The track will feature courses focusing on space physiology and research using ground-based spaceflight models, and students will learn first-hand about specific space life sciences topics from scientists who are conducting state-of-the-art research with NASA.

To obtain additional information on the Space Life Sciences PhD Track at the University of Houston go to **http://www.hhp.uh.edu/space-life-sciences/default.cfm** or download a copy of the brochure in pdf format at **http://hacd.jsc.nasa.gov/documents/2009_SLS_PhD_Curricular.pdf**.



Research Elements Overview

The Program uses the 6 elements to mitigate human health and performance risks and to establish the evidence base on which human spaceflight health standards are based. These standards include fitness for duty standards that define the physiological and behavioral parameters necessary to maintain performance; the permissible exposure limits during spaceflight conditions; and levels of care standards that define the medical capabilities needed to respond to a medical contingency. The descriptions and detailed accomplishments for each element are discussed in the following sections.

The elements include:

- International Space Station Medical Project
- Space Radiation
- Human Health Countermeasures
- Exploration Medical Capability
- Space Human Factors & Habitability
- Behavioral Health & Performance

International Space Station Medical Project

The International Space Station Medical Project (ISSMP) provides the bridge between flight research and medical operations by planning, integrating, and implementing human research requiring access to the ISS, Shuttle, Soyuz, Progress, or other spaceflight vehicles. This support spans preflight and postflight ground activities and in-flight science operations, and also includes access to on-orbit assets including sustaining engineering of the Human Research Facility. During 2009, the ISSMP coordinated and optimized the research supporting 5 Shuttle missions (STS-119, 125, 127, 128, 129) and 5 ISS missions (Increments 18–22). In addition, the ISSMP successfully certified and delivered flight hardware on the first flight of the JAXA H-Transfer Vehicle (HTV) to contiune support of on-orbit research operations.

In 2009, 4 investigations completed all in-flight operations and 4 studies continued in-flight operations. Also in 2009, 9 new investigations began initial flight operations and 5 new investigations initiated development of flight procedures and flight hardware. The following table provides a list of all ISSMP flight experiments, their required subject number, 2009 progress, and status to date.

Current International Space Station Medical Project Flight Investigations

Investigation Title	Ops Title	Subjects			Status (as of December 2009)
		Required	Completed		
			2008	2009	
Nutritional Status Assessment	Nutrition	24	6	11	Increment 21–22 crewmembers participating , flight samples returned from Increments 18–20 and analysis in progress
Cardiovascular and Cerebrovascular Control on Return from ISS	CCISS	6	2	6	Final ISS crewmember participated during Increment 20

Investigation Title	Ops Title	Subjects			Status (as of December 2009)
		Required	Completed		
			2008	2009	
Sleep-Wake Actigraphy and Light Exposure during Spaceflight	Sleep	All STS 20 ISS	47 STS 7 ISS	64 STS 9 ISS	Study successfully recruited ISS crewmembers for Increments 20–25
Validation of On-Orbit Methodology for the Assessment of Cardiac Function and Changes in the Circulating Volume using "Braslet-M" Occlusion Cuffs	Braslet	10 scans	5	10	Investigation completed during Increment 19, data analysis in progress
Validation of Procedures for Monitoring Crewmember Immune Function	Integrated Immune	17 STS 17 ISS	10 STS 5 ISS	18 STS 8 ISS	Study successfully recruited ISS crewmembers for Increments 21–26, Shuttle phase of study has been completed
Spaceflight-Induced Reactivation of Latent Epstein-Barr Virus	Epstein Barr	41 STS 17 ISS	36 STS 18 ISS	45 STS 18 ISS	Investigation completed, data analysis and final report in progress
Behavioral Issues Associated with Long-Duration Space Missions: Review and Analysis of Astronaut Journals	Journals	10	10	11	Investigation completed, data analysis and final report in progress
Bisphosphonates as a Countermeasure to Spaceflight Induced Bone Loss Preflight Zoledronate Infusion as an Effective Countermeasure for Spaceflight-Induced Bone Loss and Renal Stone Formation	Bisphosphonate	10	0	2	Initial in-flight operations began in 2009, additional crewmembers participating in future ISS missions
NASA Biological Specimen Repository	Repository	All	5	10	Crewmembers participating during Increment 21–22, Flight samples returned from Increments 18–20, recruitment continues for all future ISS missions
CSM Harness Supplemental Development Test Objective (SDTO): A New Harness for Use with Exercise Countermeasures – Validation of Improved Comfort and Loading with the Center for Space Medicine (CSM) Harness	Harness	7	0	2	Initial in-flight operations began with Increment 20, additional crewmembers have completed the informed consent process
Spinal Elongation and its Effects on Seated Height in a Microgravity Environment	Spinal	23	0	9 STS 2 ISS	Successfully completed flight operations for first crewmembers during 2009, operations continuing with additional Shuttle and ISS subjects

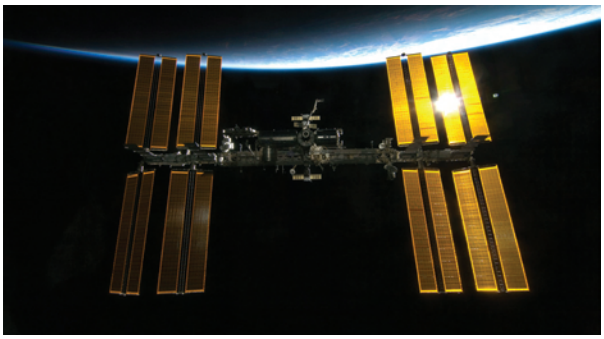
Investigation Title	Ops Title	Subjects			Status (as of December 2009)
		Required	Completed		
			2008	2009	
Cardiac Atrophy and Diastolic Dysfunction during and after Long-Duration Spaceflight: Functional Consequences for Orthostatic Intolerance, Exercise Capacity, and Risk of Cardiac Arrhythmias	Integrated Cardiovascular Analysis (ICV)	12	0	2	Following significant development time, the initial in-flight operations for this study began in 2009, additional crewmembers participating in future ISS missions
Maximal Oxygen Uptake during Long-Duration International Space Station Missions	VO_2max	12	0	3	Due to flight hardware issues, initial flight operations were delayed until late 2009, operations began during Increment 20
Reaction Self Test on ISS	Self Test	24	0	0	Selected for flight in late 2008, investigation began operations with one crewmember during Increment 21 and has successfully recruited additional crewmembers for future ISS missions
Physiologic Factors Contributing to Changes in Postflight Functional Performance	FTT	13 STS 13 ISS	0	3 STS 0 ISS	Selected for flight in late 2008, investigation completed testing of 3 Shuttle crewmembers, additional crewmembers from both Shuttle and ISS missions will continue in 2010
Human Factors Assessment of Vibration Effects on Visual Performance during Launch	Visual Performance	up to 9 STS	0	5	Crewmembers completed this investigation that will provide data for the development of the Crew Exploration Vehicle, multiple ISS missions are planned in 2010
Dietary Intake Can Predict and Protect against Changes in Bone Metabolism During Spaceflight and Recovery	Protein-K	12	0	0	An expanded version of the Nutrition investigation scheduled to begin flight operations during Increment 22
Intravenous Fluid Generation for Exploration Missions	IVGEN	N/A	N/A	N/A	Advanced technology will be tested and evaluated during this flight hardware demonstration planned for the STS-131 mission in 2010
A Comprehensive Characterization of Microorganisms and Allergens in Spacecraft Environment	SWAB	8 sessions	0	2	The initial water collections were successful completed in support of this investigations in 2009
An Integrated Resistance and Aerobic Training Study for the Validation of an Exercise Countermeasures Regimens Aboard the International Space Station	iRATS	40	N/A	0	Selected for flight in late 2009, flight operations are currently scheduled to begin with the Increment 27–28 crewmembers

Assessment of Operator Proficiency following Long-Duration Spaceflight	Manual Control	12	N/A	0	This investigation completed the flight feasibility assessment and pending completion of the ground phase will be processed for select for flight
Biomechanical Approach for Optimization of ISS Exercise Countermeasures	TBD	6	N/A	0	A new flight investigation currently in flight definition process

The ISSMP works with the Space Medicine Division, other Program elements, and International Partners to return the data needed to address key human risk areas. The ISSMP coordinates with the Space Station Payloads Office to streamline the processes for station usage, to increase the research output, and to maximize the sets of data that can be returned to guide future research to meet the objectives of the risk reduction program. To learn more about the ISSMP, please visit **http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-issmp.html**.

2009 Highlights

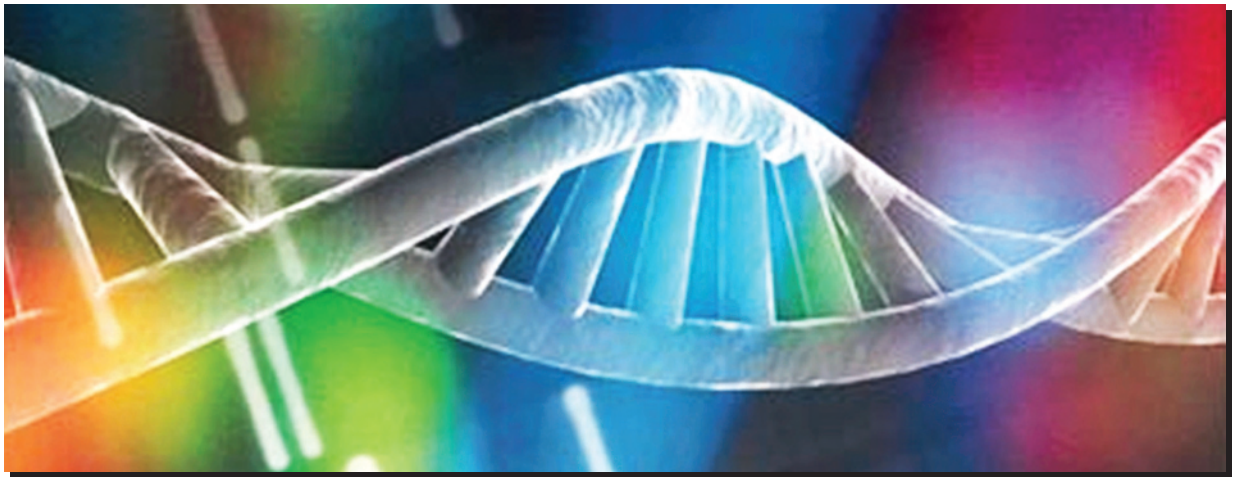
ISS 6-Person Crew



With completion of the assembly phase, 2009 marked the beginning of 6-person crew operations on the ISS. With 6 crewmembers aboard the ISS, the number of scientific investigations increased significantly. The ISSMP played a vital role in supporting the in-flight science operations from conducting preflight crew informed consent briefings, scheduling pre- and postflight baseline data collections, providing real-time console support for flight operations, and developing and maintaining flight hardware and software. To support the multi-discipline research investigations, the ISSMP coordinated the development and launching of supplies on the NASA Space Shuttle, Russian Soyuz and Progress, the ESA ATV, and the JAXA HTV vehicles. Support for these investigations extended to launch and landing sites in the U.S., Russia, Europe, and Japan. NASA and the International Partners will continue to fully utilize the ISS as a research laboratory.

Urine Monitoring System Interface Testing with Russian ACY

The urine monitoring system (UMS) underwent interface testing with the Russian Waste Collector System (ACY) in Russia in 2009. This test verified power and thermal interfaces between the systems. The testing was successfully completed and the engineering unit was returned to JSC. The UMS is currently planned for launch on STS-133 in September 2010.



Space Radiation Element

The goal of the Space Radiation Element is to ensure that the crews can safely live and work in the space radiation environment without exceeding the acceptable radiation health risks. Space radiation differs from radiation encountered on Earth[1]. Health risks from space radiation pose acute and lifetime risks to astronauts which may include an increased incidence of cancer, acute radiation sickness, degenerative tissue damage such as heart disease and cataracts, and early and late central nervous system (CNS) damage. Space radiation risks have clinically relevant implications for the lifetime of the crew. For this reason, space radiation studies rely on biomedical, genetics, computational chemistry, and radiation physics expertise to provide:

- Recommendations for acceptable space radiation permissible exposure limits for exploration missions
- Radiobiological research on the mechanisms of health risks from space radiation and the acquirement of radiobiology data for the different types of space radiation at doses and dose-rates of interest to NASA
- Development of biophysical risk projection models and computational tools to assess and project crew risk of cancer, CNS, degenerative tissue damage, and acute radiation syndromes from space radiation
- Computational tools and models to assess and verify vehicle designs for radiation protection
- Assessment of technology developments for monitoring radiation exposure and recommendations on technologies to be used operationally
- Potential reductions in risk projections to enable radiation protection design and crew constraints for lunar and Mars missions
- Assessments of the effectiveness and development of physical or biological countermeasures

[1]The primary sources of radiation in space are galactic cosmic rays, which consist of protons and electrons trapped in Earth's magnetic field and solar particle events. Galactic cosmic rays permeate interplanetary space and include high ionizing energy particles. They cause damage at the cellular and tissue levels unlike the damage caused by terrestrial radiation such as x-rays or gamma rays because of the significantly higher ionizing power, greater potential for radiation-induced damage, and greater penetration power of high ionizing energy particles.

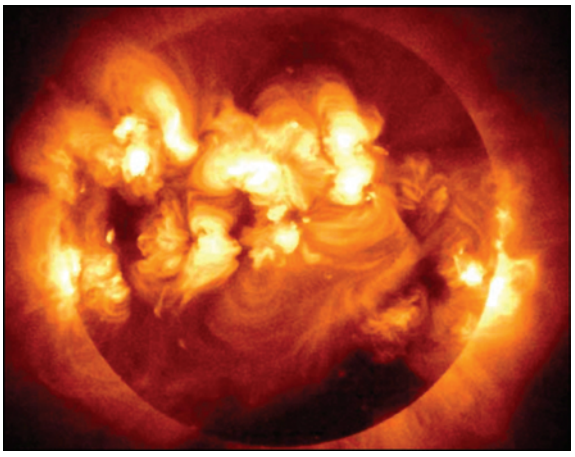
The results of space radiation studies contribute to human exploration by providing the scientific basis to accurately project and mitigate health risks. The radiobiological and physics research guide and support risk assessment and protection strategies. The results will also provide tools for evaluating shielding recommendations for habitats and vehicles as well as requirements for storm shelter and early warning systems for solar particle events.

Cancer risks pose the largest challenge for exploration with the uncertainties in cancer risk projection having large impacts on lunar and Mars mission designs, limiting NASA's ability to adjust mitigation measures such as shielding and biological countermeasures. For the CNS and degenerative risks, there are uncertainties in the dose thresholds and latency. Clinical significance of the various diseases that may occur include: death from heart disease to in-flight performance disruption due to severe CNS changes or cataract progression. Acute radiation sickness is possible if adequate operational procedures and shielding are not provided and research is needed to optimize radiation protection practices in these areas. To read more about the Space Radiation Element, please visit: **http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-srpe.html**.

2009 Highlights

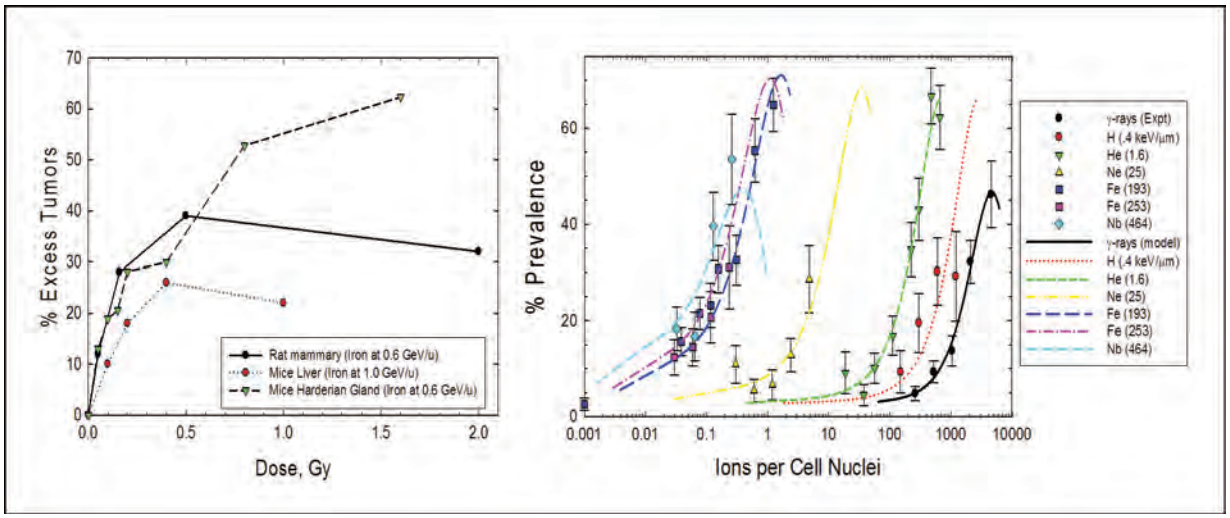
Radiobiology and Countermeasures Research

The Space Radiation Element funds external investigators through peer-reviewed solicitations to perform ground-based research in the area of space radiation biology using beams of high-energy heavy ions simulating the space radiation environment at the NASA Space Radiation Laboratory (NSRL) at the Brookhaven National Laboratory. Research results on human health effects by researchers at LaRC and JSC will enable the development of accurate risk projection models, future development of biological countermeasures, and identification of crew constraints for mission planning and operations. Key research findings published in scientific journals include:



Composite Image of Multiple Solar Flares on the Sun

- Results indicating a low relative biological effectiveness (RBE) for leukemia from heavy ions than previously thought
- Results indicating a high RBE for liver and lung tumors from heavy ions and new evidence of non-targeted effects in tumor development
- Results establishing the importance of the intercellular matrix in DNA damage and genomic instability as shown in 2D and 3D organotypic cell culture models of human lung, colon and breast tissues



Iron Induced Liver Tumors in Mice (Left) Compared to Earlier Studies of Iron Induced Mammary Tumors in Rats (Right)

New results from M. Weil et al. (Radiation Research, 2009) of the Colorado State U. NSCOR (PI R. Ullrich) (left panel) for iron induced liver tumors in mice are compared to earlier studies of iron induced mammary tumors in rats and Harderian gland tumors in mice. After adjusting for difference in iron energies and competing risks from other tumor types in the different studies, the results suggest a standard tumor induction curve for solid tumors by iron with a very high RBE. These results are best described by a non-target effects model as shown in the right panel for the Harderian Gland tumors for several ions types, where a shallow dose response for heavy ions occurs at low doses (Cucinotta and Chappell, *Mutation Research*, 2009) and indicates an increasing RBE as dose is lowered or for chronic exposures to heavy ions.

OLTARIS Design Tool

OLTARIS Design Tool Website Homepage

The Space Radiation Element develops and maintains an integrated tool set that collects the current best practices, databases, and state-of-the-art methodologies to evaluate and optimize space radiation protection for human systems such as spacecraft, spacesuits, rovers, and habitats. The On-Line Tool for the Assessment of Radiation in Space (OLTARIS) radiation design tool website was significantly enhanced to include updated light ion and neutron transport, multi-layer transport in user specified materials, the calculation of back-scattered neutrons, and voxel-based human geometry models to more accurately calculate effective dose. These accomplishments establish the basis for ray-by-ray transport with backward/forward neutron generation within spacecraft and lunar surface geometries. Identified customers specifically performing work for NASA include industry for the Orion vehicle, commercial developers of space transportation systems, and extravehicular activity (EVA) suit systems; Orion's Vehicle Integration Office Radiation Systems Team; Constellation's Lunar Surface System elements and mission trade studies; SBIR Radiation Shield Material developers; as well as academia collaborating on nuclear physics and transport research. Access to a broad user community performing work for NASA is maintained via the OLTARIS website. **https://OLTARIS.NASA.gov**

Probabilistic Risk Assessment Model for Solar Proton Events (SPEs)

Solar particle events (SPEs) occur with significant frequency (5 to 10 per year) and differential onset times, fluence or numbers of particles, and energy spectra. Most SPEs (~90 percent) lead to very small organ doses even for light shielding. To support spacecraft design, a statistical model of SPE propensity, fluence, and energy spectra was developed using a data base of SPEs for solar cycles 19 to 23 and historical data since the 15th century from nitrate samples collected from Arctic-ice cores. The model allows for shielding design to specify protection levels to be implemented (Kim, Feiveson, Hayat, Cucinotta, *Health Physics*, 2009).

Measurement Technology

The Space Radiation Element completed technology development of a portable standard reference monitor. Also, in collaboration with the SBIR program and the NSBRI, the Space Radiation Element is completing a neutron spectrometer prototype and continues development of a lunar EVA spacesuit dosimeter with additional testing of these devices in 2010.

High Precision Measurement System with Remote Laptop Interface Designed to be used as a Standard Reference for Earth-Based Testing of Radiation Dosimeters for the ISS, Moon, and Beyond

NASA Space Radiation Laboratory (NSRL) at Brookhaven National Lab

Ground-based research in radiobiology is conducted for NASA at the NSRL using beams of high energy heavy ions simulating the space radiation environment as well as a new SPE simulator and large beam capability. To develop accurate risk models of radiation associated health effects to exploration crews and to identify countermeasures in reducing those risks, NASA principal investigators participated in 3 campaigns of several weeks in duration at the NSRL in the spring, summer, and fall of 2009. During these campaigns, over 100 experiments to irradiate a variety of biological specimens, tissues, and cells during a total of ~1130 hours of beam time yielded valuable experimental data. The new SPE simulator was first used during the spring run where low energy components of an SPE spectrum and low dose rates were tested by investigators. The large beam capability (60 × 60 cm^2 versus current 25 × 25 cm^2) was used during the summer run where a large number of samples were irradiated at the same time to optimize beam time usage. These new capabilities will support optimization (cost, schedule, capability) of future low dose-rate studies entailing long exposures, on the orders of tens of hours, for a large number of samples. The research results are published in numerous peer-reviewed scientific publications.

In addition, the electron beam ion source (EBIS) being developed with the DoE's Office of Nuclear Physics continues to make good technical progress and should be available to researchers in 2010. Upon completion, the EBIS will offer a larger array of ion species at higher beam intensities than previously available with greater operational flexibility and potential for real-time galactic cosmic ray simulation.

Experimental Beam Line at NSRL

Collaborations

The Space Radiation Element collaborates with the DoE's Office of Science to understand the risks to humans from exposure to low doses or low fluences of ionizing radiation. The Space Radiation Element and the DoE's Low Dose Radiation Research Program, Basic Biology and Modeling, jointly support 9 grants focused on elucidating molecular mechanisms and pathways involved in normal radiobiological responses to low dose exposures. The Space Radiation Element also collaborates with international entities such as ESA, JAXA, the Italian and Russian Space Agencies, and the European Union in Radiobiology Research Program, and is participating with the International Council of Radiation Protection on recommendations for radiation protection in space.

Human Health Countermeasures (HHC) Element

NASA uses the term “countermeasures” to describe the procedures, medications, devices, and other strategies that help keep astronauts healthy and productive during space travel and return to Earth. The HHC is responsible for understanding the normal physiologic effects of spaceflight and developing countermeasures. Before in-flight-testing, candidate countermeasures and technologies are developed and refined using ground-based studies and flight analog environments. Example analog environments include hind-limb suspended animals, head-down tilt bed rest, undersea habitats, and Antarctic outposts.

The HHC comprises 5 projects that address exercise, non-exercise, and extravehicular activity (EVA) countermeasures and provides flight analog facilities and computational modeling to help test and integrate potential countermeasures before flight verification. Major 2009 accomplishments are described by each HHC project:

- Exercise Countermeasures
- EVA Physiology Systems and Performance
- Flight Analogs
- Non-Exercise Physiological Countermeasures
- Digital Astronaut

To learn more about the HHC, please visit **http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-hhc.html**.

Exercise Countermeasures Project (ECP)

The ECP is responsible for developing effective, efficient exercise protocols and hardware to maintain astronaut health and fitness during long-duration space missions and to preserve the capability to perform mission critical tasks both in transit and while on the planetary surface. The ECP conducts ground, spaceflight analog, and flight studies to address risks and knowledge gaps. Additionally, the ECP sponsors research that will inform the Human Spaceflight Medical Standards that relate to muscle and cardiovascular health.

2009 Highlights

Functional Task Test (FTT)

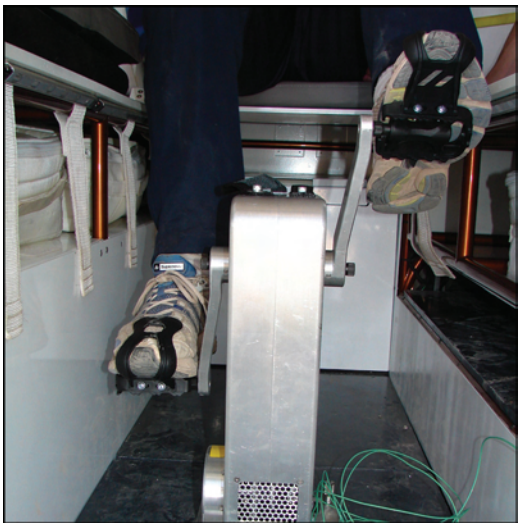
STS-128 marked the first postflight data collection for the "Physiologic Factors Contributing to Postflight Changes in Functional Performance" (short name Functional Task Test). The FTT is an interdisciplinary protocol that maps cardiovascular, neuromuscular, and sensorimotor responses with performance of mission-specific functional tasks. Functional tasks were developed based on expected exploration mission activities. Performance data is collected during these mission task simulations, before, and after Shuttle and ISS spaceflight missions. A battery of cardiovascular, neuromuscular, and sensorimotor physiologic tests are performed in conjunction with the functional tests. The FTT test findings will indicate the types of activities that are expected to be impacted during future planetary exploration, and inform development of targeted countermeasure protocols to mitigate losses and maximize crew health and performance.

In addition to finalizing the FTT test protocol based on test/re-test reliability, muscle performance pilot test findings, and multiple end-to-end simulations to rehearse the entire protocol, the FTT investigator team deployed over 15,000 lb of FTT hardware to KSC and Dryden Flight Research Facility (DFRF) in preparation for the first Shuttle postflight testing that occurred in September. After hardware set up and verification at KSC and DFRF, the team completed postflight data collection on the STS-128 and STS-129 crews, along with preflight testing on the STS-131 crew and Expeditions 22/23 and 25/26 crews. The FTT study will include data from up to 9 Shuttle and 15 ISS crewmembers.

A Test Subject Performs the Ladder Climb, Object Translation, and Construction Board Functional Task Simulations (from left to right) While Instrumented with Test Hardware during a Pilot Study for the FTT

Lunar Electric Rover (LER) Ergometer

For the crew to maintain muscle mass, strength/endurance and to recover from strenuous tasks, confined postures and minor muscle injuries, the LER is required to have the capability and volume for the crew to conduct both aerobic and resistive exercise for 30 continuous minutes each day. GRC members of the ECP developed a prototype ergometer to fulfill this requirement. While requiring no vehicle power to operate, the ergometer actually delivers power through use. The ergometer provides aerobic exercise in a compact stationary cycle and can also be used for upper body resistance exercise.



Crewmember's Perspective Cycling on the LER Ergometer during September 2009 D-RATS Trial

Desert Research and Technology Studies (D-RATS) Field Trial

Testing of the prototype ergometer occurred during D-RATS trials. For the 3-day field trial in 2008, a demonstration of the exercise ergometer was conducted. In September 2009, the D-RATS trial lasted 14 days, whereby the crew used the exercise ergometer for 12 out of 14 days at least an hour per crewmember per day. Of the 16 human factors assessed during the trial, the crew rated 10 of these as acceptable with only minor improvements desired. Improvements are being made for the next D-RATS evaluation in 2010 and requirements are being developed for exercise capability for a Generation II rover (planned to be evaluated in 2011). In the "Quick Look" summary to the Constellation Program Manager after the 2009 trials, the team stated that the "Ergometer worked great in the LER, was valuable and made the 14-day mission doable".

LER Traversing Terrain at D-RATS 14-day Trial

Evaluation of Maximal Oxygen Uptake (VO_2max) and Submaximal Estimates of VO_2max before, during, and after Long-Duration International Space Station Missions

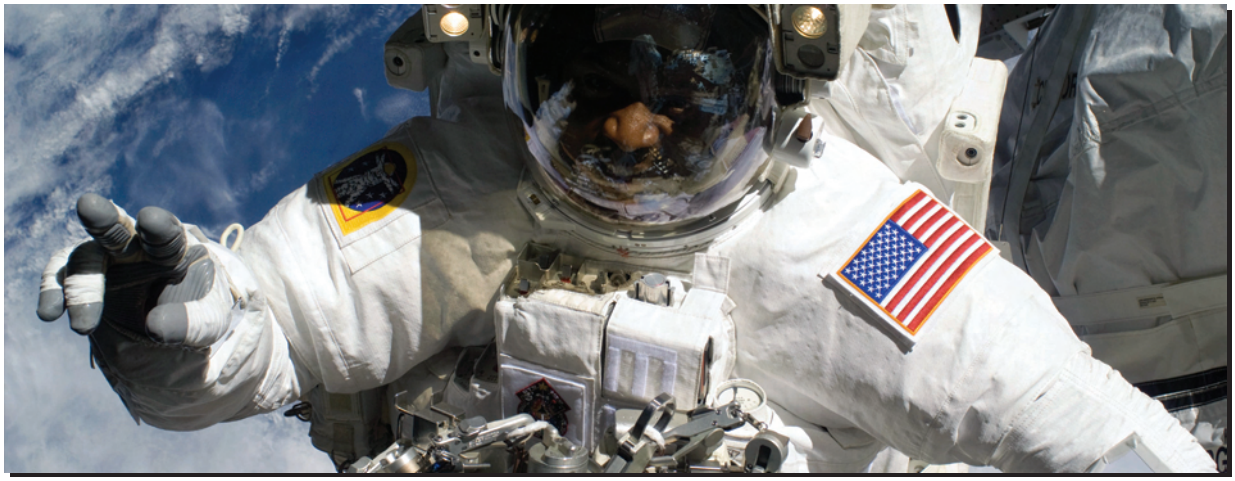
Crewmember Performing Maximal Exercise Test on the ISS Using the CEVIS and the ESA Portable Pulmonary Function System

The objectives of the VO_2max experiment are to directly measure aerobic capacity during and following long-duration missions, to assess the validity of current methods to estimate VO_2max change during and following the ISS missions, and to determine whether the accuracy of VO_2max change estimation can be improved by approaches such as the addition of submaximal VO_2 and cardiac output measures. This flight investigation involves measurement of the crewmembers' aerobic capacity by means of the direct method of oxygen uptake during maximal exercise, the first time this has been done during long-duration spaceflight. The ESA's portable pulmonary function system (PPFS) is being used to collect all metabolic test variables. This investigation will yield data to determine if the current approximation of aerobic fitness, which uses the heart rate response to the cycle ergometer with vibration isolation and stabilization (CEVIS) exercise work rates, provides sufficient data to accurately characterize the changes induced by spaceflight; or whether more comprehensive measurements should be incorporated into the routine assessment of the crew's cardiovascular exercise capacity. Twelve crewmembers will take part in this investigation and the first VO_2max flight investigation was performed by 4 crewmembers on Increments 20 and 21.

Treadmill Harness

The first crewmembers aboard the ISS to participate in the Harness Supplemental Development Test Objective (SDTO) completed their protocols between September and December 2009 (June – November 2009). The crewmembers completed 16 of 16 planned data collection sessions with both the current "treadmill harness" and the new harness developed at GRC. The data consists of direct measurements of load data in the shoulders and hips provided by buckle transducers as well as subjective feedback on harness comfort by the crewmembers from an in-flight questionnaire administered after selected exercise sessions. Correlation of comfort and load data is expected to lead to a better understanding of design requirements for improved future exercise harnesses.

Crewmember Wearing the Treadmill Harness during an Exercise Session – Visible at the Rear of the Hip Belt is the Junction Box that Provides Power to the Transducers Placed in the Harness Straps



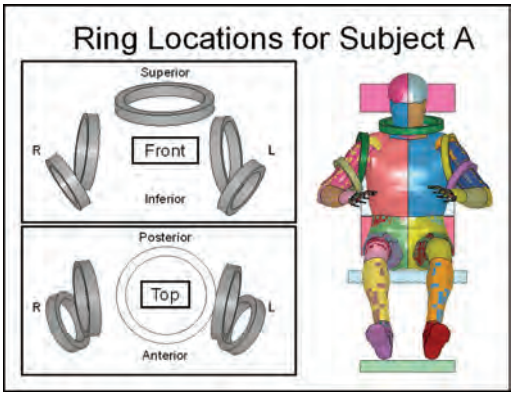
EVA Physiology, Systems & Performance Project

The EVA Physiology, Systems & Performance Project (EPSP) continues working with Program projects, the Constellation Program, and various external organizations to develop and integrate analyses of EVA-related human health and performance using modeling techniques and multiple analog environments. Data generated from project activities are aimed toward improving exploration EVA crew health, mission and task performance, and protection from injury. These data are being actively incorporated into trade studies and requirements for various Constellation Program projects, including Orion and EVA Systems, among others.

2009 Highlights

Occupant Protection

Race car and military aircraft occupant protection experience suggests that significant human safety benefits can be gained from improved seat and restraint systems. Existing NASA occupant protection requirements may not adequately account for seat/restraint systems and associated injury responses to a range of vehicle landing loads. The EPSP Occupant Protection team including subject matter experts from automotive, racing, and military occupant protection backgrounds continues to develop, verify, validate, and accredit biodynamics models that will be used by the Constellation Program to evaluate a variety of vehicle, seat, and restraint.



Analysis of Crew Injury due to Rigid Suit Elements

The modeling team compiled a dataset that includes all National Association for Stock Car Auto Racing (NASCAR) crashes from 2002 to 2008. The team preprocessed 4,015 cases to

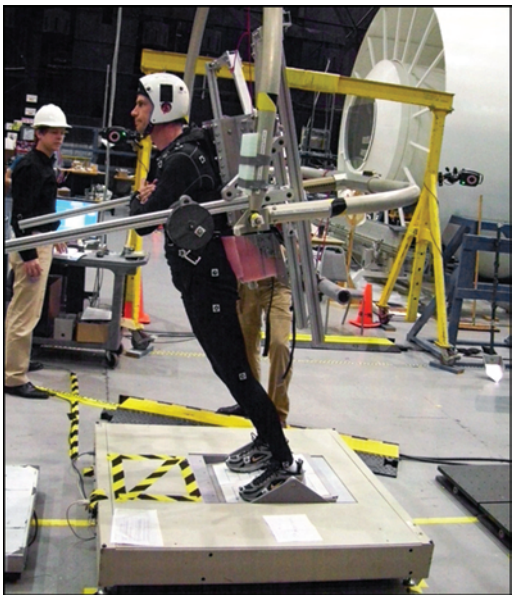
select the appropriate pulses for analysis. A subset of ~200 cases was selected to analyze in the Livermore Software, LS-DYNA®, using the First Technology Safety Systems (FTSS) Hybrid-III Automated Test Dummy (ATD) model. Approximately 125 cases have been modeled to date. These data will be used to determine the probability of human injury associated with the biodynamic responses of the Hybrid-III dummy. Results of the biodynamics models will be used in conjunction with acceptable injury risk definitions to provide improved occupant protection requirements to the Human Systems Integration Requirements (HSIR) document.

As part of the "Definition of Acceptable Risk for Orion Landing" activities, the team developed a unique injury classification system based on operational and long-term health impacts to the crew (termed the Operationally-Relevant Injury Classification Scale). This classification system was reviewed by flight surgeons and external crash and injury dynamics experts from the Air Force, Navy, Army, and auto racing industries, who determined that it represented a new and innovative approach that could yield very positive outcomes for classifying injuries for risk analysis.

Of particular concern is the interface between the suit worn by the crew and the Orion vehicle's seat. Aspects of this suit-seat interface are inconsistent with the risk assumptions of the Brinkley model, NASA's current injury requirement. The EPSP Occupant Protection team modeling efforts and sled testing programs at Ohio State University and Wright-Patterson Air Force Base are contributing valuable information to provide updated risk assessments associated with injury resulting from suit and seat design parameters.

Integrated Parabolic Flight Test Phases I and II

Phase I of the Human Performance Data Collection Series using the Mark III (MKIII) prototype suit demonstrator was completed in 2009 with performance of the parabolic flight tests and the unsuited portion of Integrated Suit Test (IST-3). Due to lift capacity issues with the existing analog facility partial-gravity simulator (POGO), the suited portion of IST-3 was postponed pending completion of another facility that will allow thorough assessment of varied suit mass on EVA performance. EPSP personnel are working with developers of the new facility, the active response gravity offload system (ARGOS), to provide requirements and design concepts to optimize use of the system for human performance testing. It is anticipated that early, single-axis ARGOS tests may begin in 2010. Soon thereafter, the EPSP plans to initiate Phase II of testing.

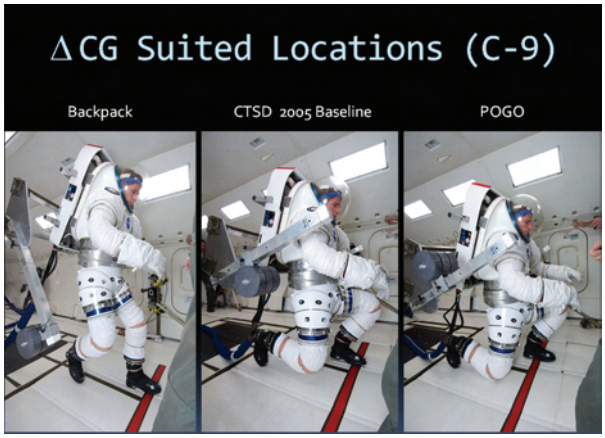


Postural Stability Test

The Phase II Integrated Parabolic Flight Test evaluated a subset of the third IST-3 center of gravity configurations and the contribution of suit mass to human performance in flight-simulated lunar gravity. This test provided POGO validation data and permitted evaluation of varied mass conditions that were not possible with the POGO. Results from

these tests indicated that changing weight alone by manipulating offload does not lead to the same human performance results that a change in weight due to a change in mass does. Additional key results were that the variability within the subject population can be extremely high and demonstrated the need for more thorough subject characterization.

Throughout the year, integrated tests continued in reduced gravity analog environments. EPSP team members coordinated integrated data reviews of the entire Phase I testing series with test team members, stakeholders, and customers to reach agreements regarding data interpretation and presentation format. The final reports for all of the ISTs are nearly complete; with the EVA Walkback Test report published (NASA/TP-2009-214796), the reports for ISTs 1 and 2 in the approval cycle, and IST-3 and the C-9 test soon to follow in 2010. Data collected during all tests, including ISTs, parabolic flight, NASA Extreme Environment Mission Operations (NEEMO) missions, and the Haughton-Mars project were evaluated together into an assimilated package presented to the EVA Systems Engineering Panel in early December. The purpose of this presentation was to inform the Constellation's EVA Systems Project Office on the initial results of these EVA systems tests, provide recommendations for forward work, and describe the importance of emphasizing optimized human performance for EVA systems development.

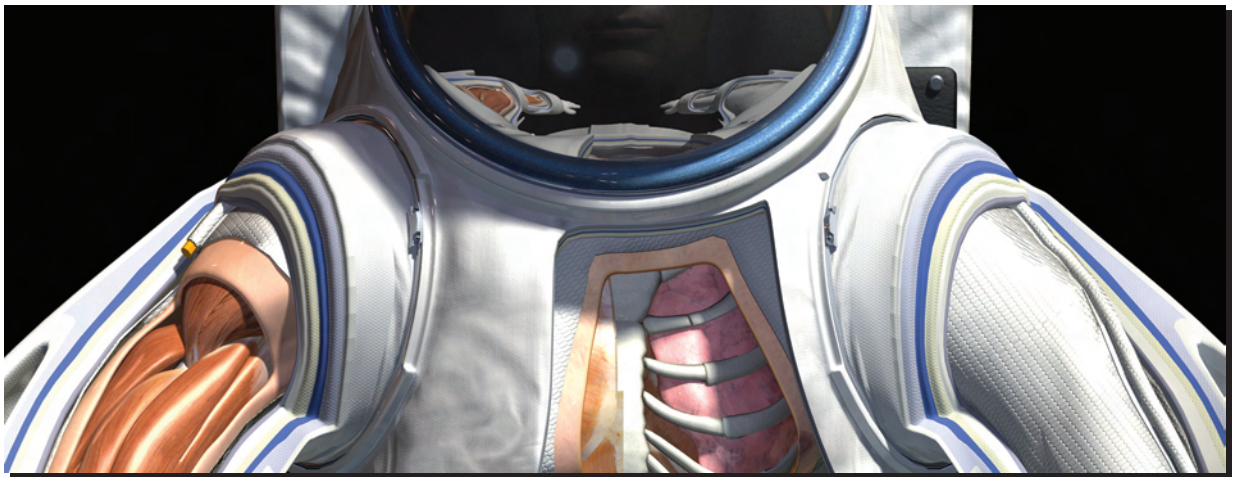


Center of Gravity Locations Tested during the Phase II Integrated C-9 Test

The USAF School of Aerospace Medicine (USAFSAM) Altitude Decompression Sickness Research Database (DCS Database) contains extensive information on over 3,000 altitude exposures conducted using standardized procedures and endpoint criteria that contributed to the development of the Altitude DCS Risk Assessment Computer (ADRAC) model at Brooks City-Base, TX (Brooks). However, the ADRAC model accounts for only 3 levels (rest, mild, and heavy) of activity in its calculations, each of which span a considerable range of metabolic rates and as a result may introduce significant error. Altitude decompression studies conducted at Brooks between1984 and 2005 showed an apparent relationship between exercise intensity and DCS incidence; however, the actual metabolic cost of these activities was not quantified.

Metabolic Cost Study

To more precisely determine the relationship between DCS incidence and activity level during altitude decompression, this metabolic cost study duplicated the testing conditions of 4 exercise profiles used in the earlier DCS studies to quantify the metabolic rate during each activity. Subjects were matched to those from the previous studies to the extent possible for age, gender, height, weight, body mass index, body fat, and VO_2peak. Breath-by-breath metabolic rate was determined for each activity using a portable COSMED© K4b2 metabolic measurement system. Data collection was completed in 2009 and results indicate a strong



Non-Exercise Physiological Countermeasures Project

The Non-Exercise Physiological Countermeasures (NxPCM) Project addresses cardiovascular, immunological, skeletal, nutritional, pharmacological, and neurovestibular (sensorimotor) physiology in an operationally-driven research program seeking to understand and, if possible, mitigate spaceflight human health and performance issues. During 2009, the project research portfolio contained 31 ongoing flight and ground research studies performed by intramural and extramural investigators across the 6 physiologic disciplines.

2009 Highlights

Stability of Pharmacotherapeutic and Nutritional Compounds (Stability)

The pharmaceuticals payload for the stability study included 4 identical pharmaceutical payload kits containing 31 medications in different dosage forms. Environmental monitoring indicated that mean temperature and humidity were comparable on the ground and in space. Cumulative radiation dose, however, was significantly higher and increased as a function of time in space. While results from this pilot study will be formally published in 2010, preliminary conclusions based on standard physical and chemical parameters of stability indicate percentage of label claim for drug content decreased below the allowable U.S. Pharmacopeia (USP) limit for many formulations and the rate of degradation for some formulations was faster in space. A small number of pharmaceuticals were stable beyond their expiration dates. The small number of replicates used in this pilot study was too small for the degree of changes, or any statistical significance to be determined. Remaining factors possibly affecting stability in space include vibration, cumulative radiation dose and re-packaging of dosage forms from their original commercial dispensers.

In November 2008 the final Stability Study kit (4 of 4) was returned on STS-126 after a 28-month stay on the ISS. The final nutrition samples were analyzed, data analysis completed, and the report was published in the *Journal of Food Science* in August 2009. The conclusions of this manuscript reported:

> "Although we generally did not see an effect of spaceflight on nutrient stability, it was

important to document that, and the changes in nutrient content with long-duration storage. As a result, this study documents the need for mitigating time-related nutrient degradation during long-duration storage. Different packaging or other means to increase shelf life of nutrients in the food system will need to be developed for exploration-class missions that could exceed 3 years. Evaluation of nutrient degradation over time and its impact on nutrient provision to astronauts at the time of consumption is required. Given the many factors involved in getting from the point of food production and packaging to actual consumption on orbit, delays can lead to an extremely long interval. This might, at least in part, help explain the changes in nutritional status observed in crewmembers. If nutrient degradation is not responsible for some status changes, then the lack of spaceflight effect on nutrient content of food, documented here, would suggest that changes in crew nutritional status after flight represent metabolic changes as opposed to dietary causes. Determining the extent and causes of changes in crewmember nutritional status will require extensive work that will be critical to continued safe exploration of space."

Stability Kit and Kit Contents

Publication: Zwart SR, Kloeris V, Perchonok M, Braby L, Smith SM. Assessment of nutrient stability in foods from the space food system after long-duration spaceflight on the ISS. *J Food Science*, 74:H209-H217, 2009.

Polar Vitamin D study, Polar 2 Vitamin D Study, and Vitamin D Dosing Study

Obtaining vitamin D is critical for space travelers because of the lack of ultraviolet light exposure and an insufficient dietary supply of vitamin D. Despite the provision of 400 IU vitamin D supplements to the early ISS crewmembers, vitamin D status was consistently lower after flight than before flight and in several crewmembers it had decreased to levels considered clinically significant. Vitamin D has long been known to play a role in calcium metabolism and more recently its noncalcitropic functions have been recognized. According to the results of several recent studies, functionally relevant measures indicate that the lower limit of serum 25 hydroxyvitamin D (a marker of vitamin D status) should be raised from the current 23 nmol/L to 80 nmol/L. The mean preflight serum 25-hydroxyvitamin D (25-OH vitamin D) for the U.S. ISS crewmembers to date is 63 ± 16 nmol/L, and after a 4- to 6-month spaceflight it typically decreases 25 to 30 percent despite supplementation (400 IU/d). The suboptimal pre- and postflight vitamin D status is an issue that needs to be addressed to allow NASA to better define the appropriate amount of supplemental vitamin D to serve as a countermeasure against vitamin D deficiency in astronaut crews.

A series of ground-based and flight studies in multiple models were conducted, including Antarctica in winter months when Ultraviolet-B (UV-B) radiation levels are essentially zero, bed rest where subjects are not exposed to UV-B radiation for 60 to 90 days, in free-living

individuals in Houston, and in the ISS crewmembers. These studies evaluated dose regimen, efficacy, compliance, and toxicity of vitamin D. Findings from the first Antarctic study (Polar Vitamin D) were published in 2009. The second Antarctic study (Polar 2 Vitamin D and Immune) will extend findings from the first study with subject testing performed at McMurdo Station during winter-over 2009 and will seek to understand the interrelationship between vitamin D and the immune system. Subject testing also was completed in 2009 for the Vitamin D Dosing Study with publication of results expected in 2010.

McMurdo Station in Antarctica, the Location for the Polar Studies

Together, the data from these studies will enable researchers to provide space crews with evidence-based recommendations for vitamin D supplementation. The findings also have implications for other persons with limited UV light exposure, including polar workers and the elderly.

Publication: Smith SM, Gardner KK, Locke J, Zwart SR.Vitamin D supplementation during Antarctic winter. *Am J Clin Nutr*, 89:1092-8, 2009.

Nutrition Supplemental Medical Objective (SMO)

The Nutritional Biochemistry Laboratory study "Nutritional Status Assessment" (Nutrition SMO) continued in 2009 with additional analyses from completed subjects, continued collection of samples on orbit, and sample return on every visiting Shuttle flight. Initial data documented that vitamin D levels are being maintained at preflight levels with recommended supplementation at 800 IU/d, an increase from the initial supplement dose of 400 IU/d. Collagen crosslink excretion during the ISS missions indicates the same 100 to 150 percent increase in excretion of bone resorption markers as observed in the Skylab and Mir crews. Review of data from crewmembers after activation of the advanced resistive exercise device and crewmembers participating in the bisphosphonate experiment are critical next steps. The laboratory received additional samples that were returned on STS-129 in November and completed data collection on 9 subjects. This study will continue to provide insight into individual and small group effects (e.g., countermeasures - pharmacological, exercise, dietary, gender differences, etc.) and possibly better identify gender differences.

Crewmember Storing Nutrition SMO Samples

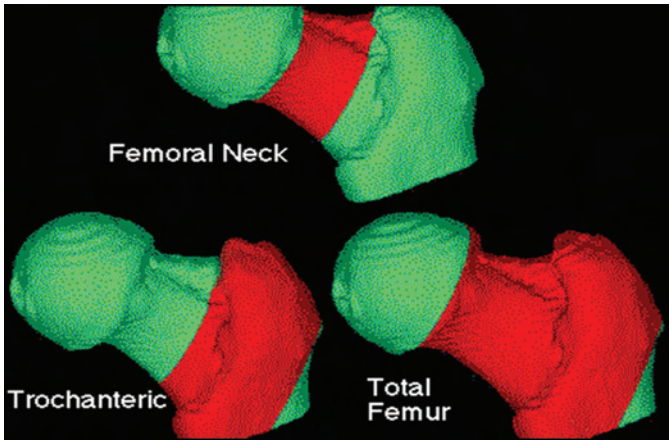
Integrated Immune SMO

The Integrated Immune SMO study characterizes in-flight immune response of crewmembers. The short-duration portion of the study successfully closed with a final 'n' of 18 completed crewmembers. Also, 6 long-duration ISS crewmembers completed the study, for a study total of 8 long-duration subjects completed to date. From a technical perspective, the study continues to perform flawlessly. Live cells are being returned from orbit within the allowable time constraints for maintaining viability and allowing immune functional data collection reflecting the in-flight condition to be achieved. Also, immune data is correlating well with both stress and viral reactivation data, allowing some mechanistic conclusions to be derived. A mid-point assessment is planned for January 2010, where final Shuttle and ISS data to-date will be analyzed. A progress report was to be delivered at the HRP Investigators' Workshop in February 2010.

In-Flight Collection Kit used for the Integrated Immune Investigation

Bisphosphonate Study

The ISS Increment 18 mission marked the first completion of flight participation by a crewmember in the bisphosphonate investigation. The purpose of this joint NASA JAXA research study is to determine whether bisphosphonates, in conjunction with standard in-flight exercise, will protect long-duration crewmembers from the decreases in bone mineral density documented on previous ISS flights. As of late 2009, 2 in-flight subjects returned and a third will return from a 6-month flight in early 2010. The fourth subject launched in late 2009. The study team analyzed the data collected thus far and the results were communicated to the subject. Additional activities in 2009 included multiple updates to the Master Protocol and Layman's Summary to reflect the most current safety-related information from the literature, the JSC's Committee for the Protection of Human Subjects renewal of the study protocol, and participation in a successful medication compliance review by an outside consultant regarding the storage and handling of alendronate.



QCT Analysis of Bone Compartments in Femur

CHOICE – Consequences of Long-Term Confinement and Hypobaric Hypoxia on Immunity in the Antarctic

Summer Staff arriving at Concordia Base on CD-3 Aircraft

The Immunology Discipline continued working toward evaluating and validating a ground analog to spaceflight with an international collaborative study in the Antarctic. Early in 2009, the winter-over 2009 crew entered isolation. At deployment, the ESA and NASA scientists successfully processed entry-samples on location at Concordia Base and characterized the early-deployment adaptation phase. Samples were successfully processed and analyzed on location using a deployed cytometer, which is a change from immunology standard operating procedure for other locations where samples are usually processed and returned to JSC for analysis. An ESA scientist performed continued testing during the winter-over period, using leftover reagents from the entry testing period. Raw data were e-mailed out as bandwidth allowed and analyzed at the JSC.

Integrated Cardiovascular Study

The Integrated Cardiovascular Study is a unique flight study that is the combination of 3 selected studies to maximize resources. This is an important study expected to quantify the extent and time course of cardiac atrophy and identify its mechanisms. During 2009, 2 portable ultrasound machines were purchased to support the U.S. and Russian baseline data collection, and the study began flight operations with the first in-flight data collection session occurring at the beginning of August.

Midodrine Study, as a Countermeasure for Post-Spaceflight Orthostatic Intolerance (Midodrine Study) Recommendation

Interim results of the Midodrine Study were evaluated at the Human System Risk Board. The board decided that the potential side-effects and interactions with other medications outweighed the benefit of the use of midodrine as a countermeasure. The discontinuance of the study was due to the concern that midodrine may negatively interact with promethazine (Phenergan®), a medication used to control severe motion sickness. The data analysis was concluded and the final report was completed in September 2009.

Flight Analogs Project

The Flight Analogs Project (FAP) supports a variety of investigations using ground-based, bed rest analogs. Bed rest is a well established spaceflight analog to study changes in physiologic function associated with reduced gravity and spaceflight. A battery of biomedical tests, called standard measures, are conducted on each subject to assess immune function, nutritional status, cardiovascular responses, exercise responses, neurological function, and bone physiology before, during, and after bed rest. The Flight Analogs Project also supports coordination of human research participating in ground-based missions for other analogs environments such as the NEEMO Aquarius facility in Key Largo, FL; Haughton-Mars Project in Devon Island, Canada; D-RATS, AZ; and research stations in Antarctica.

Current Ground-Based Analog Environments

Study	Question	Duration	Subjects Needed	Subjects Completed	Status
Lunar Analog Feasibility Study	Is the lunar bed rest model a feasible simulation of the affects of lunar gravity on the human body?	6-day bed rest	23	23	Completed
Gender Differences Bed Rest Study	What causes the difference in orthostatic hypotension between men and women postflight?	60-day bed rest	34	21	Ongoing
Daily Bone Loading Exercise Countermeasure Bed Rest Study	Can treadmill exercise that is equivalent to pre-bed rest activity inhibit bone loss experienced in bed rest?	84-day bed rest	12	0	Pending start
Lunar Analog Pilot Study	What are the physiologic responses to 30-days of head-up tilt bed rest?	30-day bed rest	12	0	Pending start

2009 Highlights

Lunar Analog Feasibility Study

Subject Sitting in the Head-Up Tilt Bed Rest Analog

As NASA plans to return to the moon, understanding the physiologic changes that occur in a 1/6-G lunar environment is critical. The Lunar Analog Feasibility study was designed to develop a bed rest analog that produces some of the physiologic changes expected in a 1/6-G environment. The study initiated in spring of 2008, was conducted at the NASA Flight Analogs Research Unit at the University of Texas Medical Branch in Galveston, TX. Participants lived in this special research unit for the entire study and were fed a carefully controlled diet based on the NASA spaceflight nutritional requirements. The goals of the feasibility study were to: (1) verify that the 9.5-degree angle imparts a 1/6 body weight loading through the subject's long axis, (2) assess short-term subject comfort and tolerability of a 9.5-degree head-up tilt bed rest model, and (3) assess the body's fluid redistribution in the head-up tilt bed rest analog.

There were 3 phases involved in this study: pre-bed rest, bed rest, and post-bed rest. Subjects spent 13 days in the pre-bed rest phase to stabilize their diet and collect baseline data to assess their body fluids. Participants were free to move around inside the bed rest facility and do normal activities. For the second phase, bed rest, study participants were in the Lunar Gravity Simulator bed at a 9.5 degree head-up tilt 16 hours each day for 6 days. A force plate placed at the foot of the bed measured force along the long axis of the body. Subjects were permitted to both sit and stand in the bed. During standing, 1/6 body weight loading was verified. Subjects slept horizontally at night. The standardized diet was continued throughout this phase. To simulate fluid redistribution expected for the lunar environment, compression stockings in combination with foot and ankle movements were used. Subjects documented their level of comfort a number of times each day throughout the 6 days of bed rest.

Subject Standing in the Head-Up Tilt Bed Rest Analog

Redistribution of body fluids was assessed at the end of day 6 of bed rest. The final phase of post-bed rest involved 2 days of reconditioning and subjects were free to move about the facility. After these 2 days, participants were released from the facility.

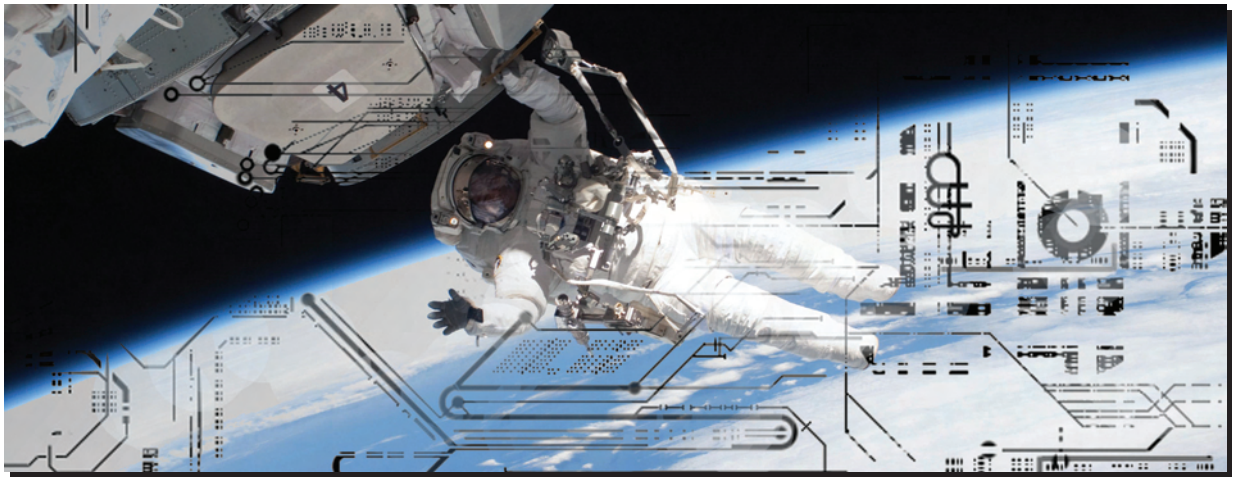
Results indicate that 9.5-degree head-up tilt bed rest analog successfully achieved the 1/6 body weight load along the long axis of the body. Assessment of comfort throughout the bed rest phase indicated that subjects comfortably tolerated this bed rest analog for the 6 days

spent in bed. Body fluids demonstrated fluid loss as would be expected in a reduced gravity environment.

This feasibility study provided critical information toward development of this head-up tilt bed rest model. The next step in the process of developing this model is to allow subjects to remain in bed for a longer duration (30 days) and more fully assess the physiologic response to this model.

University of Texas Medical Branch Long-Duration Campaigns

In September 2008, damage to the University of Texas Medical Branch (UTMB) hospital from Hurricane Ike caused Flight Analogs Project studies to be suspended. Within 7 weeks the short-duration Lunar Analog Feasibility study was able to restart. Damage to the hospital affected the long-duration studies to a greater degree. These studies were successfully restarted in February 2009. This restart provided an opportunity to implement changes to the standard measures complement and shorten the duration of bed rest studies to 60 days. These changes provide the ability to obtain the necessary scientific measures in a shorter-duration study. This will allow the Program to complete studies more quickly and better align the study duration with International Partners for collaboration.



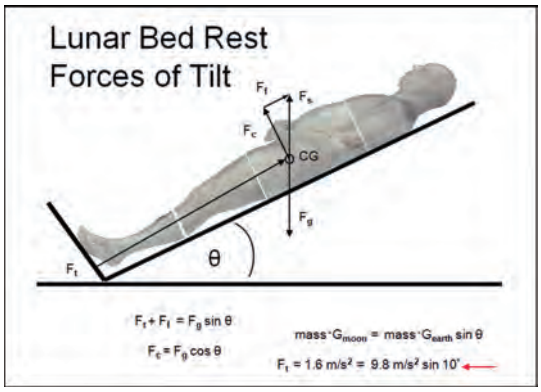
Digital Astronaut Project

Predicting the effects of spaceflight on the human body is challenging. Longer, more physically demanding missions necessitate a better understanding of human physiology during spaceflight to establish health and safety requirements for these missions. The Digital Astronaut Project is working to develop a detailed computer model of the entire human body. The JSC is the lead center for the project with the GRC serving as a key collaborator focusing on code validation and module development. In addition, the computational backbone is an adapted form of a simulation developed at the University of Mississippi Medical Center over the past 40 years. The current version of the code is known as the DigitalHuman.

This model will be useful to predict the effects of spaceflight on each body system. Scientists are already using the model to provide detailed systems analyses and examination of the mechanisms of physiologic adaptation of humans to microgravity and extraterrestrial environments. The computer model also may be useful to the medical community to aid in understanding disease and lead to improvements in pharmaceuticals, surgical procedures, and treatments.

2009 Highlights

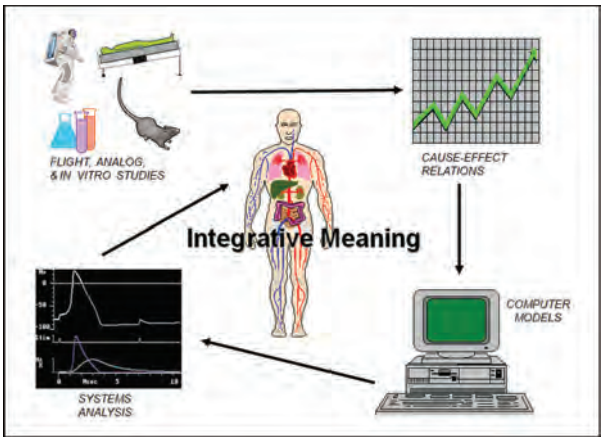
Systems Analysis in Support of HRP



The systems analysis team of the Digital Astronaut Project supported the Lunar Analog Feasibility study by serving as a platform for developing experimental protocols to be used. The model was used to compare the theoretical differences in physiologic adaptation that could be expected between actual lunar habitation and the proposed bed rest analog. The Digital Astronaut Project also served as a theoretic platform for the analysis of potential cardiac adaptations that might be noted after long-duration spaceflight. These preliminary studies were performed to prepare the model for a more advanced analysis of forthcoming Integrated Cardiovascular Analysis data.

DigitalHuman Module Development

In 2009, module development continued to extend the capabilities of the DigitalHuman, specifically in cardiovascular modeling and function. Finite element simulations of whole heart function, developed by the National Center for Space Exploration Research, were and continue to be used to investigate the response of the heart muscle to unloading in microgravity, as well as the change in local muscle strain due to this unloaded condition. The results of this study will be compared and contrasted to spaceflight data to elucidate if changes in heart function, which may be detrimental to spaceflight and return, can be attributed to unloading conditions.



Verification and Validation of the DigitalHuman Model

To ensure adequate functionality and enhance user community confidence of the base DigitalHuman Code, the Digital Astronaut Project instituted a comprehensive verification and validation (V&V) activity. The V&V process was developed using NASA 7009, the NASA document Standard for Models and Simulations, content and seeks to address the relative credibility of the model in the areas of its intended use. Due to the history and complexity of the DigitalHuman Code, the V&V process takes the approach of quantitatively evaluating the performance of the simulation environment in simulating conditions reported in peer-reviewed literature of spaceflight and space analog environment studies. Due to the relatively sparse data in the referent sources, quantitative comparison is carried out using procedures and processes first developed for computational fluid dynamics but modified for the DigitalHuman physiologic parameter space. To date, 8 peer-reviewed studies, ranging from Skylab 4 to acute response to lower body negative pressure, have been reproduced for simulation in the DigitalHuman environment. Seven additional simulations, focused on short-term Shuttle missions, are near completion.

Beta Review of the DigitalHuman Code

Twelve investigators from around the world participated in the beta review of the DigitalHuman v1.0 model, the integrated physiology simulation environment of the Digital Astronaut Project. To ensure a comprehensive review of the model, the project invited reviewers with expertise in physiology, behavioral science, space habitat systems, aerospace medicine, and mathematical modeling. The reviewers evaluated the software system on (1) fidelity in simulating physiologic responses; (2) ease of use with respect to implementing simulations and acquiring required data; and (3) adequacy of the online user documentation and support provided by the Project. Reviewers provided valuable feedback on the strengths and weaknesses of DigitalHuman, which the Project is working to address in a prioritized order.

Exploration Medical Capability (ExMC) Element

During missions to the Moon or to Mars, the crew will need medical capabilities to diagnose and treat injury or disease as well as maintain crew health. The ExMC Element develops medical technologies, data handling capabilities, and clinical procedures for different levels of care during space missions. The ExMC Element develops medical technologies for in-flight diagnosis and treatment as well as data systems that protect patient's private data, aid in the diagnosis of medical conditions, and act as a repository of relevant NASA life sciences experimental studies. To minimize the medical risks to crew health, the physicians and scientists in the ExMC Element develop models to quantify the probability of medical events occurring during a mission. They define procedures to treat an ill or injured crewmember who does not have access to an emergency room and who must be cared for in a microgravity environment where both liquids and solids behave differently than on Earth.

Human exploration of the Moon and Mars presents significant, new challenges to crew health:

- Hazards created by traversing lunar or planetary surfaces
- Effects of exposure to a number of different gravity environments
- Limitations on communications with ground-based personnel for consultation and diagnostic assistance for medical events

Providing health care capabilities that overcome these challenges requires new health care systems, procedures, and technologies to ensure the safety and success of exploration missions. In addition, exploration levies new requirements on data management. The ExMC Element is developing new approaches to catalog information so that it can be queried and analyzed. New methods are needed to train medical personnel who may not have access to experts for consultations. Developing these capabilities are the goals of the ExMC.

2009 Highlights

Exploration Medical Condition List

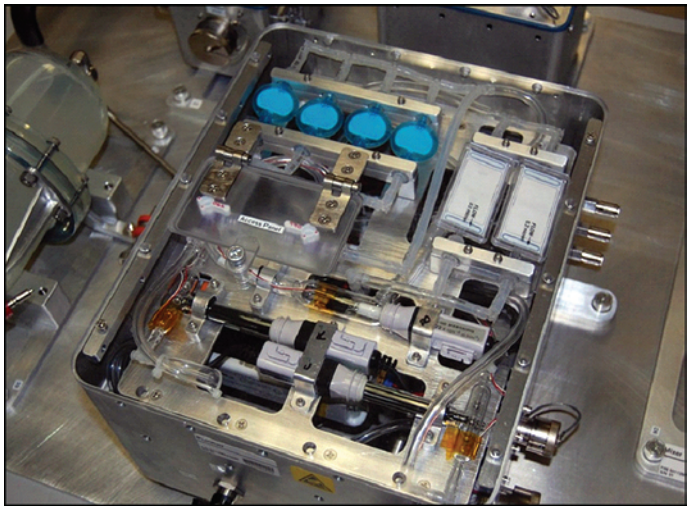
The Exploration Medical Condition List (EMCL) was created to define a set of medical

conditions that are most likely to occur in spaceflight. Derived from the overarching Exploration Medical Capabilities risk of "the inability to adequately treat an ill or injured crewmember", the EMCL is categorized into distinct lists based on the various Constellation Program mission profiles. Currently, the mission profiles that have been evaluated include nominal mission profiles of Orion to the ISS transfer mission, and the Lunar Sortie and Lunar Outpost Missions. The contingency mission profiles that were evaluated included contingency return mission to Earth from the ISS, Lunar Sortie, Lunar Outpost, and a 144-hour depressurization return.

The EMCL was generated from existing medical operations sources, such as the ISS medical checklist, the Shuttle medical checklist, the Longitudinal Study of Astronaut Health in-flight occurrence data, and the NASA flight surgeon Delphi study, which were consolidated into one general list of conditions that were applicable in spaceflight. A clinical priority was then assigned to each condition based on the mission profile. Since each condition has a likelihood and consequence rating, a risk posture can be established and a risk management plan can be developed to allocate resources to control or mitigate high risk medical conditions.

Mixed Water Generation and Intravenous (IV) Drug Mixing Capability

The intravenous fluid generation (IVGEN) system developed at GRC successfully completed a critical design review in November 2008. Throughout 2009, efforts were spent building the flight hardware and preparing for the required reviews before hardware turnover scheduled. In November 2009, IVGEN personnel turned over the portion of the flight hardware that will fly in the Multi-Purpose Logistics Module (MPLM). The remainder of the flight hardware will be turned over for orbiter middeck stowage in February 2010. The hardware is scheduled to launch in March 2010, with operations slated for April 2010.



IVGEN Assembly that Purifies Water Coming from the Space Vehicle

Integrated Medical Model (IMM)

The IMM is a software-based decision support tool useful to mission planners and medical system designers in assessing risk and designing medical systems for the constrained environment of spaceflight. The IMM provides an evidence-based approach to optimize medical resources and minimize risk within spaceflight operational constraints of mass, volume, and logistics. The IMM quantifies knowledge across the space medicine, in-flight operations, engineering, training, and research domains. This quantified knowledge is used in the context of a mission and crew profile to forecast risks to crew health and mission success. The process of building and validating the IMM adheres to probability risk assessment

techniques described in NASA Procedural Requirement 8705.5 and NASA STD 7009 – Standard for Models and Simulations. The IMM uses current evidence-based information to establish a defensible position for making decisions.

Stochastic computational methods (Monte Carlo simulations exceeding 20,000 trials) are used by the IMM to forecast probability distributions of crew health and medical resource utilization, as well as estimates of the risk of medical evacuation and loss of crew life. The following table lists the inputs and outputs of the IMM.

Number of Crew and Mission Duration	Quantity and Type of Medical Events
Crew Attributes (e.g., age, gender)	Medical Resources Used and/or Depleted
Mission Activities (e.g., spacewalks)	Risk of Evacuation
Medical Conditions and Likelihood	Risk of Loss of Crew Life
Mission Outcomes (e.g., evacuation)	Optimized Mass and Volume of Medical Resources
In-flight Diagnosis and Treatment Protocols and Resources (e.g., pharmaceuticals, devices)	Comparative Assessment of Crew Health for Specified Missions and In-flight Medical Capabilities
Crew Functional Impairment Estimates	Estimate of Time to Depletion of Medical Resources

For each trial in the simulation, the IMM tracks each medical event and decrements of the pharmaceuticals and supplies required to diagnose and treat each medical condition. If essential supplies are depleted, medical conditions may go untreated, and the risks to crew and mission success increase. The uncertainty of patient response to treatments is bounded via best-case, worst-case, and untreated-case algorithms.

The IMM project helps close communication gaps between the medical and engineering communities and provides a common risk language to discuss in-flight mitigation strategies. The IMM currently characterizes 83 medical conditions, 47 of which have occurred during both short- and long-duration space missions. Nine of the 83 medical conditions are due to space adaptation by the human body. The use of historical in-flight medical data, terrestrial surrogate data as appropriate, and space medicine subject matter expertise enables the development of a probabilistic, stochastic decision support tool capable of optimizing in-flight medical systems based on crew and mission parameters.

Although the IMM will not officially be in operation until October 2010, the IMM has proven valuable to both the ISS and Constellation Programs. IMM incidence and medical resource tables have been used to aid the Health Maintenance System Redesign Project. The IMM medical conditions list served as the baseline list of medical conditions for exploration medicine planning. Also, the IMM risk estimates of evacuation and loss of crew life are being used to update the ISS probabilistic risk models.

Completed Credibility Matrix following NASA-STD-7009

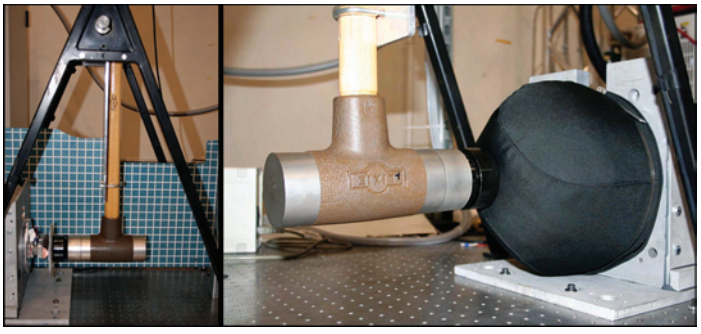
The NASA 7009 software standard requires that each agency software product have a credibility score, encompassing model development, verification and validation (V&V), documentation, and subject matter expert review. In support of that requirement, the IMM modeling and simulation (M&S) credibility-scoring matrix was completed to define the path for the project to plan M&S development, V&V activities, assess customer requirements for model credibility, provide links to credibility evidence documents, and track both subject matter expert and internal review scoring. The document automatically assesses the NASA STD 7009 credibility score over specified credibility factors. The accumulated data are provided to the user and the output assigns a ranking classification to the credibility factors. The matrix has been adapted and modified by other HRP modeling groups, and the matrix is under consideration as a general tool for users of the NASA STD 7009.

Credibility Scoring for the IMM Project

The radar plot above illustrates the credibility scoring for the IMM project. Each has distinct criteria for each level of scoring. The blue line indicates the level of credibility that IMM had achieved at the beginning of 2009.

EVA Hip Model Delivery to IMM

With NSBRI summer intern support at the GRC, the Suit Impact Load Attenuation Study (SILAS) developed data to allow the IMM Bone Fracture Risk Module (BFxRM) to more accurately quantify the protective nature of the astronaut's EVA suit in preventing hip fractures. The SILAS investigation quantified the base level of fracture protection provided by the EVA suit, using a unique test bed designed to quantify the force at an impact site that is an analog for a human trochanter. The BFxRM used SILAS data to demonstrate that the pressurized EVA suit provides better protection than clinically prescribed hip protectors. However, this protection was significantly dependent on the fit of the EVA suit in the hip area.



SILAS Unique Test Bed (Analog for Human Trochanter)

LSDA Bed Rest Summary Report

The ARC Life Sciences Data Archive (LSDA) provided 26-human bed rest study summaries from previous experiments to the LSDA at JSC for archiving. These summaries will be added to existing experiment data stored in the JSC's LSDA database and will be available to the research and education communities through on-line web services. These summaries and study reports address the nature of musculoskeletal and physiologic changes associated with spaceflight. Kidney stone formation, bone turnover rate, and neck and back pain were also included in these reports.

Braslet: Completed On-orbit Scanning Sessions

Braslet in Use by a Crewmember on Orbit

The study, "Validation of On-Orbit Methodology for the Assessment of Cardiac Function and Changes in the Circulating Volume Using Ultrasound and Braslet-M Occlusion Cuffs" station development test objective (SDTO) 17011-U/R (Braslet), is a collaborative effort between NASA and the Russian Federal Space Agency. The goal is to establish an ultrasound methodology for assessing a number of cardiac and vascular parameters associated with circulating volume and its distribution in long-duration spaceflight. Objective responses to modified Valsalva and Mueller maneuvers were measured by cardiac and vascular ultrasound before, during, and after temporary central volume reduction by means of Braslet-M thigh occlusion cuffs. The Braslet SDTO completed all on-orbit scanning sessions and data collection. Data continue to be analyzed, but preliminary results indicate that trends are clear and indicative of transient but substantial physiologic effects of the elements of the procedure. Initial data indicate that this project has validated the methodology to (1) address specific aspects of operational space medicine and space physiology, including assessment of circulating volume disturbances, and (2) expand diagnostic ultrasound imaging and Doppler techniques in microgravity.

Bone Fracture Detection and Medical Operations for Ultrasound Diagnosis of Fracture Training

The NSBRI ExMC team is investigating the sensitivity and specificity of expert and non-expert performed ultrasound in the diagnosis of musculoskeletal injuries. Specifically, this project determines the ability of ultrasound to characterize musculoskeletal injuries in trauma patients and develops just-in-time training methodologies for non-expert operators. Over 700 patient-subjects have enrolled and demonstrated that point-of-care ultrasound performed by non-experts is an accurate diagnostic modality that is operationally relevant for the space program. The feasibility review report was enthusiastically accepted by research and flight medical staff, and the trial is currently being expanded. Just-in-time educational methodologies also are being developed for space medicine and astronaut crews.

Analysis of Oxygen Requirement in Hypoxic Environments

The management of a major illness or trauma in space will likely result in the need for oxygen delivery. On-orbit oxygen delivery relies on oxygen stores that also provide environmental oxygen. A major concern of oxygen delivery is the elevation of ambient oxygen concentration and increased risk of fire. Previous work found that in healthy individuals, oxygen requirements can be met by oxygen delivery at 3 to 4 liters per minute. This finding suggests that oxygen on orbit could be provided by an oxygen concentrator. This device has the advantage of operating solely from electric power and since it concentrates oxygen from ambient air, does not result in increases in environmental oxygen concentration, reducing fire risk. The waste gas from a concentrator is nitrogen, resulting in a net environmental change of 0. The findings of this study suggest that even at extreme altitude, oxygen concentrators are a safe alternative to compressed or liquid oxygen. The Program is collaborating with the NSBRI and SeQual® on this analysis.

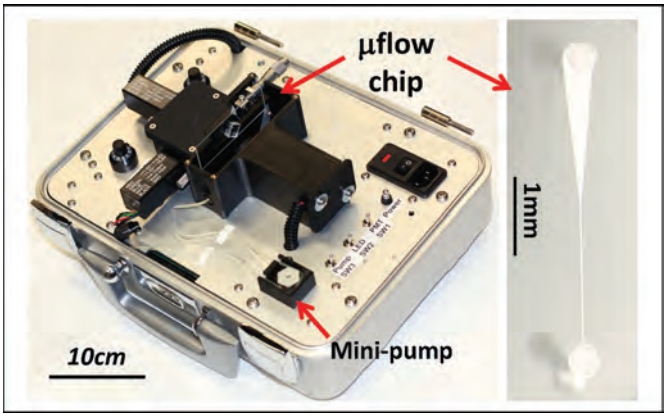
SeQual's Oxygen Concentrator Shown Next to an O_2 "d" Size Cylinder for Scale

Intuitive Ultrasound Catalog Grant for Autonomous Medical Care

The purpose of this NSBRI grant is to develop an intuitive, comprehensive ultrasound catalog and autonomous guide to allow non-expert operators to perform complex ultrasound examinations with minimal or no guidance. The catalog data architecture was completed and over 80 hours of ISS ultrasound investigations, 20 hours of preflight and postflight data, and over 20,000 still ultrasound and cabin images are in process of being added to the catalog. The preliminary functionality of the intuitive ultrasound guide was demonstrated to astronaut crews and flight medical personnel who approved the design and concept. Targeted, autonomous training models and cue cards are being developed for several organ systems. The focus of training is on an intuitive, just-in-time, educational interface for the comprehensive use of ultrasound in medical contingencies anticipated during exploration class spaceflight.

In-Flight Blood Analysis Technology for Astronaut Health Monitoring Engineering Prototype

The NSBRI grant, "Handheld Body-Fluid Analysis System for Astronaut Health Monitoring", produced a prototype in 2009. This device uses electrical impedance sensing, fluorescence optical sensing, and flow separation of blood cells. The prototype successfully demonstrated fluorescent sensing and



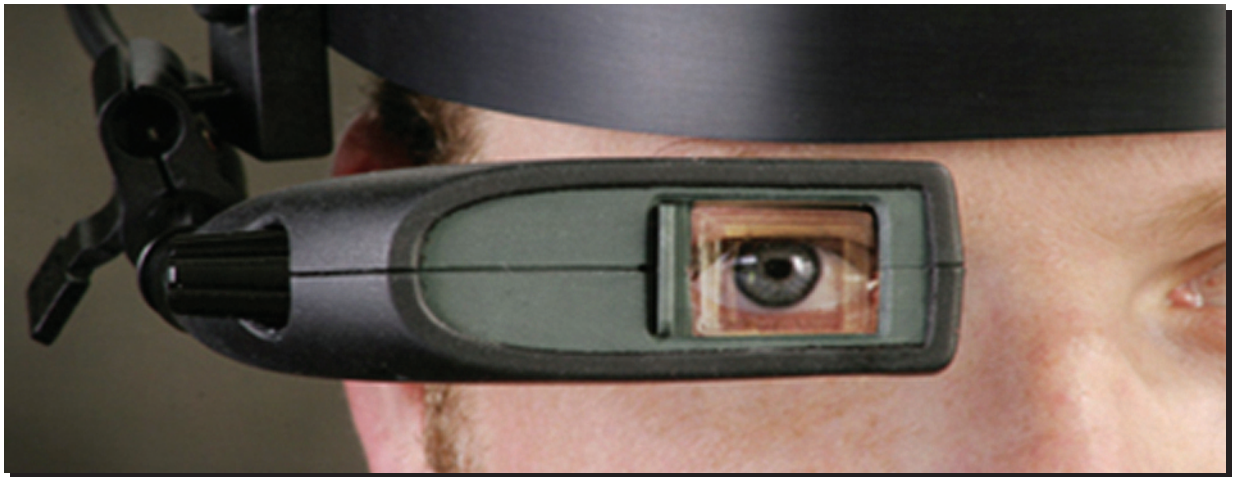
Lightweight Blood-Analysis Technology to Perform Multiple Blood Tests in Space

counting for white-blood-cell count and 2-part differential with a portable prototype micro-flow cytometer. The project is looking to extend the 2-part white-blood-cell differential to a 5-part white-blood-cell differential, add cell surface marker detection and analysis capability to the platform repertoire, and add plasma protein detection and analysis capability as well. The goal is to extend the capability of the micro-flow cytometer to enable a more comprehensive white-blood-cell differential, and allow detection of fluorescent labels attached to ligands used for cell surface marker and plasma protein detection.

Sensor and Algorithm System for Noninvasive Continuous Metabolic Rate Measurements

On future lunar missions, astronaut exploration activities will be conducted in a spacesuit or EVA suit. The suit becomes the astronaut's personal habitat, supplying oxygen, removing carbon dioxide, and maintaining appropriate temperature. During lunar surface exploration, the astronauts must have continuous real-time feedback to ensure that all consumables (oxygen, cooling water, power) last until they can return safely to their quarters. The consumption rate of these resources depends upon the metabolic rate of the astronaut during EVA tasks and the suit's ability to manage thermal loads. This NSBRI grant is to develop novel algorithms and a near infrared spectroscopy platform for real-time assessment of metabolic rate (measured as the rate of oxygen consumption [VO_2]) and muscle temperature. This capability is intended to be incorporated into biosensors that will be part of a smart system to advise astronauts about their usage of consumables during surface activities.

Astronaut Simulates Lunar Work Wearing a Prototype Spacesuit



Space Human Factors and Habitability Element

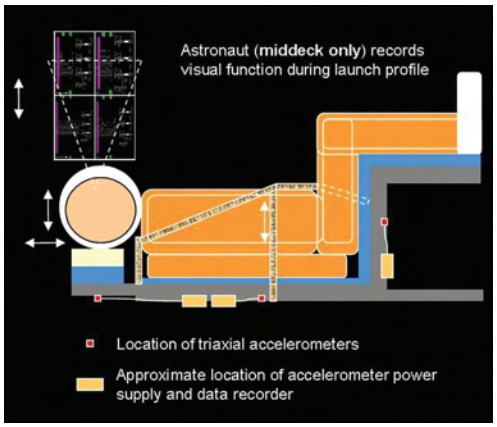
The major deliverables for the Space Human Factors and Habitability (SHFH) Element are validated models for predicting the effects of interface designs on human performance, methods for measuring human and human-system performance, design concepts for and evaluations of advanced crew interfaces and habitability systems, and requirements for spacecraft and space missions.

SHFH consists of 3 main project areas:

- Advanced Environmental Health (AEH)
- Advanced Food Technology (AFT)
- Space Human Factors Engineering (SHFE)

To learn more about SHFH, please visit **http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-shfh.html**.

The AEH Project focuses on understanding the risk of microbial contamination of the spacecraft and on the development of lunar dust exposure standards. The AFT Project focuses on reducing the mass, volume, and waste of the food system for exploration missions, while investigating processing methods to extend the shelf life of food items. The SHFE Project establishes human factors standards and guidelines for human-machine interactions to ensure optimal productivity of the crew in both physical and cognitive interfaces.



Human Factors Assessment of Vibration Effects on Visual Performance During Launch

Advanced Environmental Health (AEH) Project

The AEH Project is working towards answering important questions such as: “How potentially toxic are lunar dusts?” and “Is the crew at greater risk of infection during a mission?” The AEH Project develops vehicle design and operational requirements to decrease health risks to the crew. These answers, designs, and requirements are critical to the development of air, water, and other life support systems of spacecraft. They also drive the need for monitoring and personal protection hardware for missions to the ISS, the Moon, and future deep space missions.

2009 Highlights

During 2009, the AEH Project made significant progress in characterizing lunar dust and developing methods for toxicity testing, which included understanding lunar dust toxicity in terms of dust morphology, chemistry, reactivity, cellular effects, and whole-animal effects. Together these findings continue to improve understanding of lunar dust toxicity and point to quantitative results that lead toward the recommendation of an exposure standard in 2010.

Lunar Airborne Dust Toxicity Advisory Group

Unlike dust on Earth, which is formed by wind and water erosion and is constantly smoothed by friction, lunar dust remains jagged unless it is once again melted. Unshielded ultraviolet rays and charged solar wind from the Sun give the surface of lunar dust particles a reactive surface. On the Moon, these surfaces may remain active indefinitely. While lunar dust has properties that most toxicologists would consider moderately toxic, several unknown factors may elevate its toxicity. For example, an appreciable fraction is ultrafine dust capable of penetrating deep into the lungs. It is likely to possess surfaces activated by ultraviolet radiation. Finally, elemental iron is a major component of the respirable fraction of the dust, and iron is known to increase dust toxicity when tested in cellular systems.

Research has focused on refining methods to produce the respirable-sized dust that is needed for the toxicological studies from the limited amount of lunar soil that is available. Grinding soil by the traditional “ball-mill” technique was unsuitable because it did not produce

particles in the respirable range. Jet mills, which use high pressure gas to reduce dust size by colliding particles propelled from opposing nozzles, was found to be very effective, especially when followed by elutriation to separate smaller, lighter particles from larger, heavier ones.

The surface of lunar dust can be very chemically reactive until it is exposed to moisture. The time that is required for lunar dust to become deactivated in a habitable environment is essential to understanding its potential toxicity. Multiple studies attempting to simulate lunar activation (e.g., grinding the dust, UV irradiation, and ion implantation) consistently demonstrated that half of the original level of activation would be lost after 1 to 2 hours of exposure to room air. However, recent experiments suggest the loss of reactivity may take much longer to occur—possibly several weeks. Additional research is under way to resolve this difference and provide a value for the "activation factor" that must be considered when determining a permissible exposure limit.

In cooperation with the National Institute for Occupational Safety and Health, intratracheal instillation toxicity studies of standard dusts and authentic lunar dust were conducted in rodents. The histopathology exhibited in lungs of animals appeared to very closely resemble those of animals receiving a standard nontoxic "nuisance" dust and did not exhibit changes observed in the lungs of animals receiving a dust known to be highly toxic. Additional studies are to be conducted to confirm and extend these initial experiments.

Surface, Water, and Air Biocharacterization (SWAB) Flight Experiment

Human presence in space, whether permanent or transient, will be accompanied by the presence of microorganisms. While most are harmless or even beneficial, several microorganisms pose a threat to crew health and spacecraft system performance. In addition to infectious disease, microorganisms can be responsible for toxin production, food spoilage, plant disease, volatile organic gases, biodegradation of spacecraft materials, and the fouling of environmental systems. Environmental analyses of the Mir and the ISS have demonstrated an increase in microbial diversity and risk of contamination over the life of the ISS. Thus, understanding the microbial ecology aboard the vehicle during flight is critical to determining and mitigating risk during long-duration exploration missions to the Moon and Mars. Historically, spacecraft analysis techniques have used culture-based methodology, which contain specific nutrients designed to grow certain types of microorganisms. Recently, the development of molecular biology techniques and instrumentation have allowed a far more comprehensive evaluation of the environment than previously possible with traditional culturing techniques.

An Example of Contamination on Interior Panel in the ISS

Air and surface samples for the SWAB flight experiment were collected from the ISS before 8 vehicle dockings between Increments 13 and 18 using unique hardware flown specifically for this investigation. Water samples are currently being collected from the hot and warm dispense points of the ISS potable water dispenser. Upon return to Earth, samples were processed using a variety of techniques, including bacterial and fungal molecular identification, and quantitative techniques to identify and enumerate specific genes. These techniques include denaturing gradient gel electrophoresis, a molecular technique that allows identification of the bacteria without the need for growth on media. The organisms identified using this method differs from those previously isolated from similar sampling locations using culture techniques. Several samples were also analyzed using quantitative polymerase chain reaction to detect the presence of several viruses, including varicella-zoster virus. This organism is carried by many people and can “reactivate” under certain conditions causing the very painful disease shingles. The information collected during this experiment is critical to understanding microbial-related problems on long-duration missions. By using the data from the SWAB flight experiment and incorporating new molecular technology, NASA will better be able to mitigate the risk to crew health and vehicle integrity during exploration of the Moon and Mars.

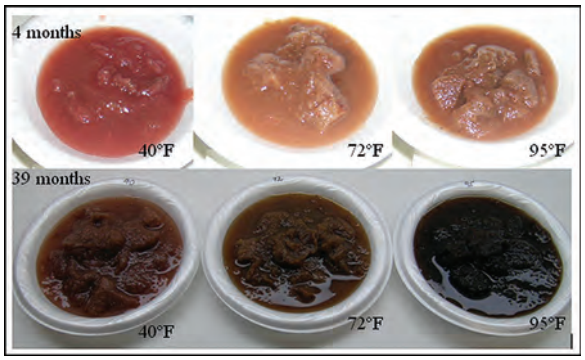
Advanced Food Technology (AFT) Project

The AFT Project is responsible for providing crews with a food system that must be safe, nutritious, and acceptable to the crew, while efficiently balancing appropriate vehicle resources such as mass, volume, waste, and food preparation time for exploration missions. This food system will require the provision of a packaged food system with a shelf life of 3 to 5 years. Current Shuttle and ISS food system technologies cannot meet these requirements. Food provides not only the nutrients needed for the survival of the astronauts, but also enhances the psychological well-being of the crew by being a familiar element in an unfamiliar and hostile environment.

2009 Highlights

Shelf Life Study of Thermostabilized Food Products

The long-term stability of thermostabilized food products is the focus of this study. Thermostabilized food is processed with an aggressive heat treatment that ensures the safety and sterility but can also result in a loss of nutrients, flavor deterioration, or other quality changes in the foods. Shelf life was defined in this study in terms of the product's nutritive value and palatability. A 3-year accelerated shelf-life study was completed on an assortment of unrefrigerated food items. Meat products and other entrées were projected to maintain sensory quality over 3 years. Fruit and dessert products were projected to maintain their quality between 1.5 to 5 years. Starches and vegetable side dishes should maintain their quality between 1 to 4 years. Egg products did not respond adequately and were found unsuitable immediately after production. Nutritional value of most products, aside from considerable losses in C and B



Rhubarb Applesauce after Being Stored 4 and 36 Months

vitamin content, appeared to be maintained throughout shelf life. Shelf-life values were extrapolated for NASA's 65 thermostabilized items with about 10 percent estimated to have a shelf life of 5 years or more and about 45 percent estimated to have a shelf life of more than 3 years. In general, the major determinants of shelf life appear to be the development of off-flavor and off-color over time. Analysis suggests that new processing technologies should be investigated to improve initial quality and extend shelf life of food products for use in long-duration missions.

Mass Reduction Trade Study

The food system for future long-duration manned spaceflights presents a challenge since maintaining the quality of the food system can result in a higher mass and volume. The Orion vehicle is significantly smaller than the Shuttle and the ISS, and the mass and volume available for food is limited. Therefore, the food team was challenged to reduce the mass of the current packaged food from 1.81 kg per person per day to 1.14 kg per person per day. The objective of the study was to determine how the mass and volume of the packaged food system can be reduced while maintaining caloric and hydration requirements and acceptability.

Meal Replacement Bars can Help Save Total Mass of the Food System

This study found that significant reductions in food system mass are possible with further menu development. With the reduction of moisture and increase in calories from fat, the system mass decreased by 321 g per crewmember per day, or 22 percent. With the substitution of standard menu items with meal replacement bars (limited to one bar per crewmember per day), the mass can be reduced by 240 g, or 17 percent. If both approaches were combined, the mass of the food system can be reduced by as much as 529 g, or 36 percent. Combining the meal replacement option with reducing moisture and increasing fat would have a net reduction from 1.81 kg to 1.28 kg per crewmember per day that approaches the overall reduction goal of 1.14 kg.

Comparison of Granola with Blueberries Packaged in Current Packaging (Left) and in a Prototype Gusseted Pouch (Right).

Comparative Packaging Study

Shelf life of foods can be reduced drastically upon interaction with moisture and oxygen. A good food packaging system functions to protect food items from exposure to these elements by providing a flexible yet firm barrier. The current rehydratable and natural form packaging system for the ISS-food system consists of a primary package enclosed within a secondary

overwrap. The primary package is a minimal barrier, transparent material (Combitherm®), which aids in processing and quality control; while the secondary overwrap is a high barrier, opaque material that ensures the product is protected and can meet the minimum shelf-life requirement of 18 months. While the overwrapped system consistently guarantees shelf life, it also generates more mass, waste, and labor than would a single material system.

Packaged Foods Provide the Crew Safe and Nutritious Meals for Long Periods of Time

A translucent, high-barrier material (Tolas®) was identified that may provide the required 18-month shelf-life without the need for an overwrap, thereby reducing the current system to a single package. An 18-month comparative packaging study is being performed to evaluate the effectiveness of the Tolas® material against current primary packaging material and a material similar to the current overwrap (Technipaq®). Dry oat cereal and peanuts and cottonseed oil, which are extremely susceptible to the effects of oxygen and moisture, were packaged in each material. The packaged products were stored at varying relative humidity levels to simulate conditions that might be encountered on the Orion vehicle. As the study approaches 18 months, results indicated that the Combitherm® material does not provide a sufficient barrier and would require an overwrap system, while the Technipaq® and Tolas® materials each appear to maintain adequate barriers on their own. The analytical testing of this study was extended for an additional 18-month period. Successful performance of the Tolas® material might allow optimization of the current ISS packaging system by reducing it to a single package.

Bulk Overwrap Evaluation

The current food system for short-duration Shuttle and ISS missions uses prepackaged dry beverages and an assortment of thermally-stabilized, irradiated, freeze-dried, and intermediate moisture foods. Many of these foods are packaged in primary packaging as well as a secondary overwrap pouch made of a high barrier, flexible, packaging material. The secondary overwrap material serves to extend the shelf life of these products by providing a protective barrier that prevents oxygen and moisture interaction with food. A bulk overwrap is being evaluated to replace the individual overwrap system used in the ISS. The system would provide a single, large overwrap that would contain and preserve one container's worth of food items within a high barrier, flexible material, similar to the individual overwrapping material.

Bulk Overwrap Saves ~20 Percent of Volume When Food is Stowed in Cargo Transfer Bags

Although this study will be completed in 2010, preliminary results indicate using a bulk overwrap instead of individually overwrapping the food packages could save the ISS nearly 50 kg/year. It also saves nearly 20 percent in volume and reduces time required to package the food by about 50 percent. The ISS program could use this concept after 2011 when the food will be stowed in full cargo transfer bags. The Orion program can use this concept for stowage of the food since hard containers cannot be used due to mass/volume constraints.

Effect of Processing and Subsequent Storage on Nutrition

Space crews rely upon the foodstuffs provided through NASA to meet their nutritional requirements. As missions extend to longer durations, the provisions have even more influence on the long-term physiology of space travelers. NASA adheres to strict requirements for the nutritional content of astronaut food during preparation. However, because vitamin degradation occurs with heat processing, oxidation, and light exposure, it is likely that the commercially sterile foods of the space program have reduced nutrient profiles at the time of consumption.

The Space Food Research Facility Retort Processes Food to Sterilize It so It Will Stay Safe for Long Periods

To evaluate the nutritional quality of current foodstuffs for prolonged space missions, a study is underway to examine the vitamin and mineral levels of space food after processing and long-storage times (up to 5 years). Replicate food samples will be analyzed for nutrient content at 1 month, 1 year, and 3 years to understand storage impact.

In 2009 15 one-year analyses and 26 one-month analyses were completed. The nutrient content of the product before sterilization processing was estimated using Genesis® R&D software, and the post-sterilization nutrient content of the food was determined through lab analysis. The 1-year products showed vitamin A continued to diminish in the package for most products over the 1 year of storage. Likewise, most folic acid and thiamin levels decreased, and vitamin C levels in all products declined from original levels by 37 to 100 percent. This study will continue until 2012.

Space Human Factors Engineering (SHFE) Project

The SHFE Project provides critical answers for the design of the next generation of NASA spaceflight systems. To ensure that humans can perform exploration missions safely and effectively, SHFE scientists and engineers conduct studies in a variety of settings, from the laboratory to analog environments to spaceflight, to collect the information needed to verify that the crew's work environment, tools, and interfaces to complex systems support their tasks. In a variety of domains, the SHFE team works closely with design and space operations experts to ensure appropriate and timely solutions to their Human-Systems Integration issues.

2009 Highlights

Spinal Elongation

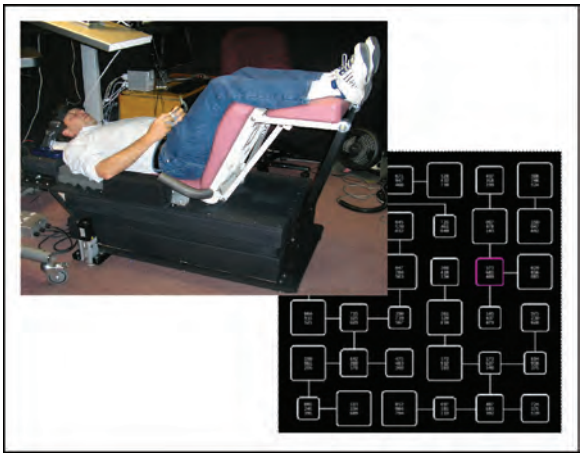
Orion designers need accurate anthropometric data to ensure that the full range of crewmembers is accommodated in the vehicle. Elongation of the spine can occur while the crew is exposed to microgravity due to straightening of the natural curvature of the spine that result from the fluid shifts in the body and the lack of compressive force on the vertebrae. As the spine straightens an increase in stature occurs. Designers are concerned that increasing the seated height may limit their design and affect crew safety and crew selection.

To collect accurate seated height data in microgravity, 3 simulated (parabolic) microgravity research flights were used to explore the methods for collecting such data. Lessons learned during these flights were incorporated into the spaceflight procedures and hardware design. The simulated microgravity flights proved to be very important for the success of collecting accurate seated height data in space.

During 2009, a custom anthropometer was fabricated and launched on a Shuttle mission. During the mission, the crewmembers collected their seated heights in microgravity after 10 days on orbit. Preliminary results showed increased on-orbit seated height, as expected. The final results will be determined once a sample size of 23 subjects is achieved. The magnitude

of spinal growth crewmembers may experience in space will affect crew safety, crew selection, and vehicle design. Without the correct anthropometric data to account for growth, a crewmember may not have adequate clearance during re-entry and landing or may not properly fit into their suit, thereby affecting crew safety.

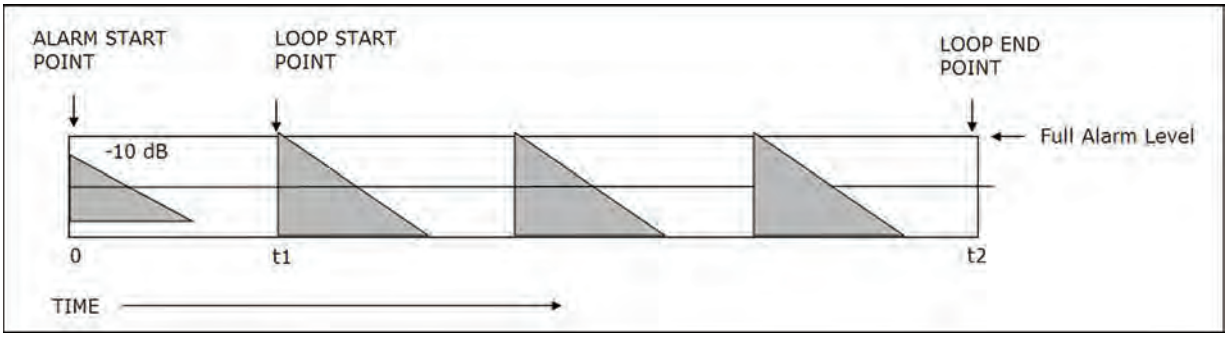
Evaluation of Intermittent and Speech-Augmented Alarms for CEV Displays



Participant in Vibration Study and Task Display

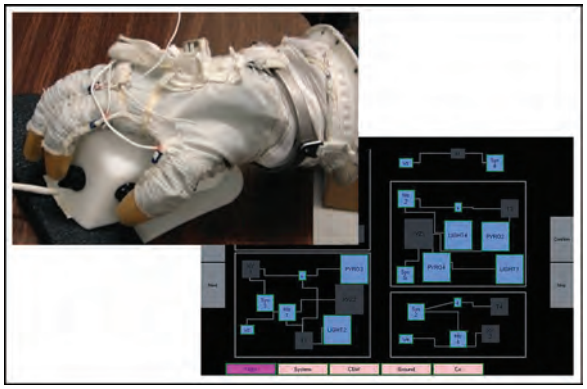
The SHFE team evaluated current audio caution-warning alarms employed in NASA flight deck displays with 6 proposed candidates. Eleven non-crew and 3 crew participants were asked to rate each candidate alarm in comparison to the current alarm for 5 categories of alert function: caution, warning, fire/smoke, and depressurization. Five of the candidate alarms were modifications of the current alarm or a runner-up alarm sound from previous studies. The sixth sound included a speech component that gave specific information about the situation. Participants rated their sound of choice for each category on perceived urgency level, overall satisfaction, and the perceived value of a potential speech component. The results show that both crew and non-crew prefer the use of a speech component.

Alarm evaluation work also supported development of Constellation User Interface Requirements. For example, the value of an initial “pre-alarm” cycle that is lower in volume than the succeeding alarm cycles was demonstrated. The inclusion of this pre-alarm greatly reduced the likelihood of undesired startle reactions. To prevent a startle effect that would be detrimental to effective response to the alarm, the first ‘pre-alarm’ iteration is 10 decibels (-10 dB) below the full alarm level. Successive iterations loop at the full alarm level from the loop start point at t1 to loop end point t2. Note that the alarms are not continuous, but instead alternate with brief periods of silence.



Conceptual Diagram Showing Pre-Alarm and Alarm Levels as Specified in HSIR Requirements

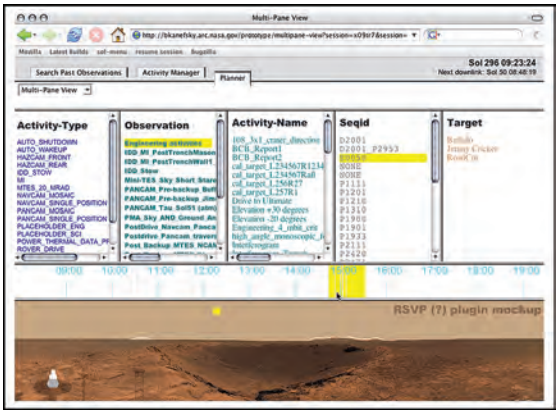
Human-Automation Interactions and Performance Analysis of Lunar Lander Supervisory Control



Cursor Control Device and Task Display

Landing a spacecraft on the Moon is a complex and challenging endeavor. The astronauts will need to work seamlessly with many systems to land safely and on target. Researchers at Draper Laboratory, along with collaborators from the Massachusetts Institute of Technology's Man-Vehicle Laboratory, the Program, and NSBRI personnel, are working to define the role of the human in complex space systems, such as a the Lunar Lander. The tasks and functions that the astronauts and computer systems each performed during the Apollo lunar landings are currently being analyzed. This investigation will be used as a basis for a performance-based modeling effort to understand the appropriate allocation of tasks as well as the effects of both automation errors and inappropriate human actions as they spread through a complex system. The researchers also are proposing to develop and integrate models that represent the human's interaction with representative vehicle dynamics to understand the effects of the information displays and interaction modality on supervisory control performance. Researchers will eventually validate aspects of these models with human-in-the-loop experiments focusing on various lunar landing scenarios. It is anticipated that this project will be an early-stage design tool that can be used to identify the appropriate task allocation between the human and automated control that is required for safe and successful lunar landings.

Scheduling and Planning Interface for Exploration (SPIFE)



A Typical SPIFE Mission Day Plan

An activity plan guides the execution of a mission, be it a spacecraft on the surface of Mars or a crew of astronauts aboard the ISS. The planning process and the plan itself also serve as a coordination tool for mission personnel from all disciplines and as a communication tool for management, scientists, the public, and other stakeholders.

The SPIFE tool dramatically improves timeline situational awareness for activities with multiple scheduling constraints. It was used for several robotic missions to coordinate various operational tasks in Deep Space Network view periods, spacecraft critical events, onboard command sequence, mission operations staff shifts, and operational planning meetings. SPIFE graphically displays timelines and event markers representing all of these elements so

that the team can better understand how they interrelate in time. As time progresses, the timelines sweep over a time bar (current time) so that operators can easily see what events should be happening currently, have recently happened, or are about to happen. SPIFE also provides a running list, updated in real time, showing the time remaining for future events, and the time since the end of past events. The tool has been used by the Jet Propulsion Laboratory and by the Program's Behavioral Health and Performance Element during NEEMO missions.

Behavioral Health and Performance (BHP) Element

The BHP Element conducts and supports research to address the risk of performance errors due to sleep loss, fatigue, circadian desynchronization, and work overload (sleep); risk of performance errors due to poor team cohesion and performance, inadequate selection/team composition, inadequate training, and poor psychosocial adaptation (team); and risk of behavioral and psychiatric conditions (B-Med).

Lunar and Mars missions will require long-duration stays in isolated, confined, and extreme environments, with extended periods of heavy workload and separation from home. Day and night cycles will differ from standard Earth time; teams composed of only a few individuals will live and work together in an increasingly autonomous scenario. The BHP is conducting operationally relevant research that will yield the deliverables, technologies and recommendations, to support the behavioral health and performance of astronaut crews and ground teams before, during, and following these exploration missions.

The B-Med Risk area aims to develop monitoring and self-assessment tools for early detection and treatment using unobtrusive and objective measures of affect, cognitive function, and other behavioral reactions to living and working in space. The Team Risk area examines team performance and cohesion gaps to develop tools and technologies that will unobtrusively monitor cohesion and performance for autonomous operations. The Sleep Risk area currently focuses on individualized countermeasure development, including lighting, medication protocols, sleep hygiene, and work-rest schedules.

The BHP's strategy for addressing its risk reduction research gaps is systematically derived and operationally driven. The end result is to optimize the adaptation of the individual and crew to the space environment and maintain motivation, cohesion, communication, morale, and productivity.

2009 Highlights

Reaction Self Test on the ISS

Handheld PVT on NEEMO

The NSBRI and the BHP are collaborating on the Reaction Self Test on ISS study, which was derived from the Psychomotor Vigilance Test (PVT) developed at the University of Pennsylvania's School of Medicine (Dinges & Powell, 1985). The PVT is a scientifically validated measure of the neurobehavioral effects of fatigue from a variety of sources with test properties that make it ideal for operational settings (Balkin et al. 2004). The reduced (3-minute) Reaction Self Test developed from and validated against the PVT has these same benefits, and like the PVT, measures vigilant attention, response speed and errors (Van Dongen et al. 2003; Dorian et al. 2003; Drummond et al. 2005). The Reaction Self Test software was developed, along with essential computer calibration equipment to ensure the test is accurate on different computers, by Pulsar Informatics, Inc. The Reaction Self Test performance algorithm was based on hundreds of test trials from astronauts engaged in NEEMO operations. The 3-minute test was validated to be sensitive to both acute total and chronic partial sleep loss in laboratory studies supported by the NSBRI, the National Institutes of Health, and the Department of Homeland Security. It has also been found to be sensitive to motion sickness and the carry-over effects of sleep medications.

The Reaction Self Test was developed to serve as both a data collection measure and an operationally relevant tool, offering astronauts a quick way to assess their performance acuity before performing critical tasks. In 2009, the test software was installed on ISS computers, and 10 astronauts consented to do the Reaction Self Test experiment. During the next 3 years the self test will be performed by astronauts on the ISS to identify how their performance is affected by acute and chronic sleep restriction, acute slam (circadian) shifts, high workload (including EVAs), residual sedation from sleep-wake or other medications used in space, and time in mission. Following each test, astronauts will receive feedback on aspects of performance. The Reaction Self Test is ultimately intended to be an autonomous aid to astronauts to use at their discretion during missions to evaluate their performance capability relative to fatigue, and when they feel fatigue countermeasures are necessary.

Russian Chamber Studies

The HRP, in partnership with the NSBRI, participated in the Institute of Biomedical Problems of the Russian Academy of Sciences' 105-day chamber study. This experiment that began late in March and ended in July served as a simulation of a 6-person ISS crew. Three NASA NSBRI BHP studies were conducted: Operational Evaluation of a Photic Countermeasure to Improve Alertness, Performance, and Mood during Night-Shift Work; Objective Monitoring of Crew Neurobehavioral Functions, and Crew Interactions; and Autonomy during Long-Duration Isolation and Confinement. These studies addressed such things as validating the efficacy and operational feasibility of a lighting countermeasure to improve alertness and performance

during night-shift work; identifying stress- and fatigue-related problems in astronauts facilitating timely assessment and interventions that could mitigate risks related to performance deficits; and informing long-duration mission planners of the psychosocial and work issues relevant to planning. Preliminary findings from all 3 studies will be presented in April 2010, with a final report anticipated later in the year.

Russian Chamber Study Habitat

Phoenix Scout Lander

In 2008, a BHP principal investigator and a multi-institutional team of co-investigators supported the ground crews of the Phoenix Scout Lander (Mars Robotic Mission) with countermeasures to help mitigate the effects of sleep loss, fatigue and circadian desynchronization. The Phoenix Scout Lander launched in August 2007 and landed at the polar region of Mars in May 2008 to study the history of water and habitability potential of the Martian surface. The ground crews supporting this mission opted to work and live on a Mars day, or “sol”, and in doing so, added approximately 39 minutes to each work day. This schedule had the potential to result in circadian misalignment, sleep disruption and performance decrements throughout the 3-month mission. Adding to the challenge, some local members of the ground crew lived with their families who maintained their normal Earth day.

Ground Support Teams at the JPL Celebrate the Mars Rovers upon Landing

The crews from previous robotic Mars missions reported adverse effects on their sleep and performance when adopting a Mars sol. As a result, the Phoenix Scout Lander principal investigator requested BHP’s support for his team. The BHP principal investigator provided blue-light boxes and practical, evidence-based recommendations for sleep and for facilitating synchronization to the Mars sol. Concurrently, the investigators collected data over the course of the mission to evaluate the effects of the schedule on the circadian system, and to assess the acceptability, feasibility, and effectiveness of the countermeasures. Study results will help inform Flight Medical Operations and Mission Operations for exploration mission planners, crews supporting Mars robotic missions, and current Shuttle and ISS missions.

Sleep Quality Questionnaire Study

The Sleep Quality Questionnaire Study uses a survey of terrestrial and flight sleep habits and experience, along with a structured, open-ended interview. The purpose of the study is to systematically capture astronauts’ experience with sleep during short-duration missions, so

that subjective sleep quality and countermeasure effectiveness can be assessed. Since July 2009, a total of 66 astronauts have completed a secure online survey regarding specific sleep strategies, crew policies, and mitigation effectiveness. In addition to the survey, each astronaut participant met individually with trained BHP and Space Medicine Division representatives for a structured, follow-up interview. Data assessment is in progress. Findings from the study will inform countermeasure strategies, as well as the development of educational materials for training current and future astronauts. Flight rules for medical operations and requirements for habitat designers will also be informed by this investigation.

Astronauts Prepare for Sleep on the Shuttle

Operational Ground Testing Protocol to Optimize Astronaut Sleep Medication Efficacy and Individual Effects

The BHP collaborated with the Space Medicine Division to complete data collection for the Operational Ground Testing Protocol to Optimize Astronaut Sleep Medication Efficacy and Individual Effects Pilot Study (Phase I Study). In this randomized placebo controlled trial, 7 participants individually spent 2 nights at the Astronaut Quarantine Facility; randomly selected on 1 night, the participant received a placebo, and on the other night, a preferred sleep-aid.

Testing was conducted using 3 validated, cognitive measures: the Psychomotor Vigilance Self Test, the Digital Symbol Substitution Test, and the Descending Subtraction Test. Additionally, saliva samples were collected to provide pharmacodynamic levels. The participant completed the testing session soon after arrival to the Astronaut Quarantine Facility, and following the completion of the session, the participant was given either a placebo or sleep-aid. Following a sleep period of about 90 to 120 minutes, the participant was awakened by a simulated ISS emergency alarm to undergo testing. Each participant was then evaluated at awakening in the morning to further assess performance degradation from medication in comparison to standard sleep inertia effects. Preliminary data analysis from the pilot study was conducted with results supporting the feasibility of the experimental methods and the likelihood that the proposed experiments will yield statistically significant findings. “Lessons learned” from the pilot study were used to revise the protocol that will be implemented in 2010.

Analog Assessment Tool (AAT)

The Analog Assessment Tool was developed by the BHP to identify optimal analogs for conducting research by utilizing a systematic process. The AAT uses an objective approach to determine the most ideal analog when implementing research that addresses BHP’s research gaps. The AAT incorporates key factors such as the spaceflight scenario, the research/deliverable addresses (ISS, Lunar Short, Lunar Long, or Mars), the relevant characteristics that are critical for addressing the gap, and the level of similarity between the space analog environment to the spaceflight mission for that characteristic. Through an

analytical hierarchy process, a rank order of “best fit analogs” is provided for addressing a specific research question. The final report of the AAT was completed in September 2009. The second iteration will begin summer 2010 and updates will be carried out in the future with annual updates planned. The AAT is unique in that it is flexible and can be adapted so that it is customized to the user and the user's needs. The design of the tool allows for the flexibility of many to benefit from its design and ultimate use and it is hoped that many researchers and research programs alike will be able to use it for their own needs.

Solid State Lighting Modules (SSLM) Pilot Study

The BHP extended its support this year to a new pilot/feasibility study evaluating physiologic and neurobehavioral effects of SSLM. Solid-state light emitted from light emitting diodes (LEDs) is an attractive candidate for replacing the general luminaire assemblies that house fluorescent lamps on the ISS. The advantages of LEDs over conventional incandescent and fluorescent lighting systems include lower upmass, power consumption, and heat generation, as well as fewer toxic materials. In addition, LEDs have greater resistance to damage and longer lamp life expectancy, making LEDs an ideal lighting candidate for the ISS and future manned space vehicles and habitats.

Two months into the study, the preliminary mock-up of the crew sleeping quarters was built with more than 50 hours of beta testing completed. The aim of the pilot study is to refine a protocol to evaluate changes in visual sensitivity, melatonin secretion, subjective alertness, objective alertness, neurobehavioral responses and possibly sleep polysomnography, following timed exposure to LED lighting in a controlled environment (similar to the Crew Quarters on the ISS). The hardware and software currently in development ultimately may allow astronauts the flexibility to adjust wavelength (color) and illuminance (brightness) from a simple graphic-user interface, an important consideration given the evidence that demonstrates different neurobehavioral effects may result from varying wavelengths and illuminances.

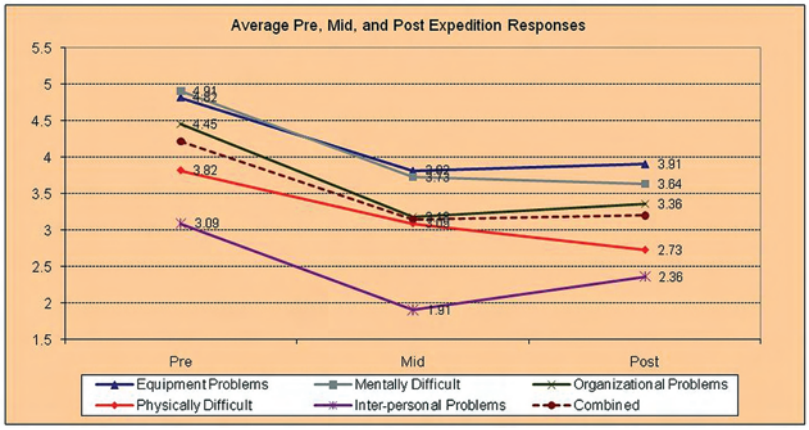
The Solid State Lighting Module Emitted from LEDs will Replace Fluorescents on the ISS

Journals Study

This study is based on the assumption that the more a person writes about a topic in a journal or diary, the more important that topic is to the person at that time. Participants in this study are asked to make journal entries at least 3 times per week while on orbit using a laptop computer. No one other than the astronaut and the principal investigator has access to the

private journal. In addition to the journal entries, participants complete a brief questionnaire before launch, at the mid-point of their expeditions, and following their return to Earth. Ten NASA astronauts have participated in this study since 2003 and all have written candidly about their expriences. Astronauts report that they benefit personally from writing in their journals because it helps them keep a proper perspective on their work and relations with others. Responses to the questionnaire show that living and working aboard the ISS is not as difficult as the astronauts anticipated before their arrival for the 6-month tour of duty.

Above: Crewmember Participating in Journals Study Aboard the ISS



Left: Pre-, During, and Postflight Responses About Life on the ISS

IMM Sleep Module/Sleep Disruption Medical Intervention Forecasting Tool (SDMIF)

Developed in partnership with collaborators at the Air Force Research Laboratory and the Institute for Biopharmaceutical Research, Inc., the SDMIF tool is designed to estimate the occurrence and impact of sleep disturbance with regard to mission planning and the need for medical interventions. Program researchers continued to make improvements that enhance the predictive capabilities of the model by focusing on assessing and implementing observed and documented occurrences of sleep enhancing medication usage. Work progresses to assess more detailed information on sleep conditions and medication usage from astronaut sleep logs to be used in model enhancement and validation.

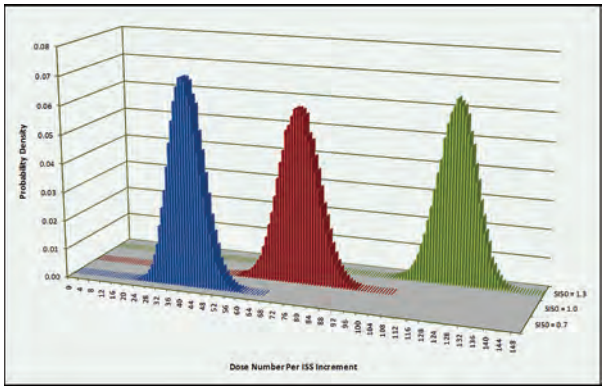


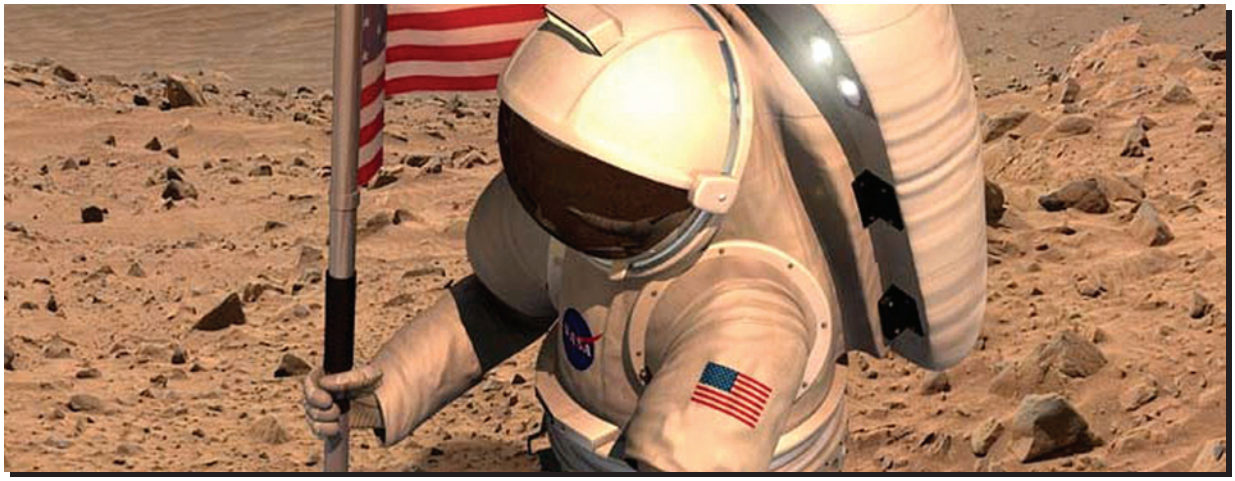
Illustration of Probability Estimates for Total Required Sleep Medication Dosage

Above is an illustration of probability estimates for total required sleep medication dosage during 180-day idealized ISS increment. SI50 refers to the sleep intensity threshold corresponding to the 50 percent likelihood for medication use. The 3 levels of SI50 are representative of a potential range of crew member differences in sleep patterns.

Fatigue Management Countermeasures (FMC) Study

Sleep loss, circadian shifting, extended wakefulness and work overload are risk factors that can not only affect astronauts before and during their spaceflight missions, but also the ground crews who support them. Mission controllers often work extended duration shifts and rotating shifts, including night shifts, and such schedules instigate significant acute and chronic sleep deprivation and consequently, fatigue. Acute and chronic sleep deprivation can adversely affect performance, safety, and personal health, increasing the risk of gastrointestinal and heart disease, impairing glucose metabolism and immune function, and substantially increasing the risk of injury due to motor vehicle crashes. The deleterious effects of fatigue are readily observed in a wide range of safety-sensitive professions and include increased risk of self-injury, higher rates of fatigue-related motor vehicle accidents, and greater incidence of serious errors.

In light of these risks, a team of expert investigators were selected to evaluate the feasibility of a Comprehensive Fatigue Management Program for the flight mission controllers program. Findings from the study will inform best methods through which to mitigate adverse consequences of fatigue on mission controllers' alertness, performance, health, and safety. The overall goals of the project include developing an online education training program and an efficient sleep disorders screening, evaluating the acceptability, feasibility and efficacy of a shorter wavelength photic countermeasure during operational night shifts to support mission controllers as they work around the clock to support flight crews.



Future Plans for the Human Research Program

As the Program begins its fifth year of operation, a major milestone will be receipt of the external Standing Review Panel reports with assessment of recommendations and associated implementation within the Program. The Standing Review Panels completed their review of the Program's IRP in December 2009, and the final reports are expected in the spring of 2010. Results of these reviews will inform the quality, relevance, and value of the research and technology developments to ensure the Program is meeting its objectives to investigate and mitigate the highest risks to human health and performance for human space exploration.

The Constellation Program will receive Program products to further vehicle and system designs. Deliverables for the Orion vehicle design will include the provision of input for the Orion Medical Kit requirements, the baseline of enhanced computational design tools for vehicle radiation shielding design assessment, and an updated Baseline Exploration Radiation Cancer Risk Projection Model V1.0. In addition, the Program will provide inputs to the integrated suit parameter recommendations for the preliminary design review of the EVA suit Configuration-1.

Subject Preparing to Run on the Standalone Zero-Gravity Locomotion Simulator

Experiment operations will continue in ground analogs and on ISS. The IVGEN and MARES hardware will launch and complete first flight operations. Radiation research will continue at the NSRL at the DoE's Brookhaven National Laboratory, the Enhanced Computational Design Tools for Vehicle Radiation Shielding Design Assessment will be baselined, and the Baseline Exploration Radiation Cancer Risk Projection Model V1.0 will be updated. The study "A Quantitative Test of On-Orbit Exercise Countermeasures for Bone Demineralization Using a Bed Rest Analog" will begin early in 2010 at the Flight Analogs Research Unit at the UTMB in Galveston, TX, where the standalone zero gravity locomotion simulator is used during bed rest analog studies to help

researchers develop improved exercise protocols and better equipment for future space explorers.

The Program will announce selections for the 2009 NRA "Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions" in April. The Program is on schedule to release 2010 NRAs in January and April for space radiation and late July for all other Program exploration biomedical research. These NASA solicitations will be in concert with the research announcement releases from the NSBRI.

The Program's Requirements Document and IRP will be updated to reflect current Program risk, gap, and task content including recommendations from the external Standing Review Panels. The Human Research Roadmap (HRR), a web-based version of the IRP, will be released and will replace the Bioastronautics Roadmap. The document effort and HRR release will further strengthen Program implementation and interface with the research community.

Human Research Roadmap

The Program made significant strides in 2009 to fortify program organization and execution, conduct research and technology developments, and provide products to the Constellation Program and to the Office of the Chief Health and Medical Officer. The Program will continue to define the challenges of human space exploration and mitigate associated risks. In 2010, the Program will continue to deliver key information and products for preventing and mitigating human health and performance risks to ensure crew health and performance and exploration mission success.

How to contact the Human Research Program:

Johnson Space Center
Human Research Program
Mail Code: SA2
2101 NASA Parkway
Houston, Texas 77058

http://www.nasa.gov/exploration/humanresearch

Back: Exercise is key to maintaining crew health and fitness to ensure mission success.

2009 Human Research Program Annual Report

National Aeronautics and Space Administration
Johnson Space Center
2101 NASA Parkway
Houston, Texas 77058
http://www.nasa.gov/exploration/humanresearch

www.nasa.gov